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FACTORS AFFECTING THE DEGREE OF INFECTION OF BARLEY BY LOOSE SMUT (*USTILAGO NUDA* (JENS) ROSTR.)[1]

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INTRODUCTION

Since 1936 studies have been conducted at the University of Alberta to determine the resistance of barley varieties and hybrids to loose smut, *Ustilago nuda* (Jens) Rostr. This report is a summary of the phases of these studies dealing with (1) method and time of inoculation, (2) relative resistance of varieties, and (3) effect of weather conditions on the success of inoculation.

Methods involving the placing of dry spores on the stigma have been described (2, 10, 19, 21). To prevent reduction in seed viability caused by the spreading and clipping of the florets at the time of inoculation, Tapke (18) devised a method in which dry chlamydospores were placed on the stigma by piercing the lemma with the points of tweezers. Moore (9) described a vacuum method in which a spore suspension is forced into the florets by the sudden releasing of air into a partial vacuum formed above the suspension covering the spike. This method, however, is not so successful with barley as with wheat. After using this and the tweezer method, Middleman and Chapman (7) pointed out that an improved technique of inoculation is necessary if fine distinctions in resistance are to be found among the different varieties. Shands (17) and Shands and Schaller (16) described a method of inoculation whereby dry spores were "puffed" from a small rubber bulb through a hypodermic needle to the stigma after the lemma was pierced. Poehlman (14, 15) used a hypodermic needle in a similar manner, but an aqueous spore suspension was used instead of dry spores.

The stage of ovary development at which inoculations are most successful is, according to Freeman and Johnson (2), the full flowering stage when the ovary just commences to enlarge after fertilization. Approximately the same stage of development has been found by other workers (9, 13, 16, 19, 21) to give highest infections when dry spores were used. It was desired to learn whether this situation obtained when a spore suspension was used.

The degree of floret opening has been considered a factor determining the resistance possessed by certain varieties (1, 2). Livingston (4), from studies of infections of reciprocal F_1 material, attributed resistance to physiologic causes. In the present study the infections of clipped and unclipped florets have been compared.

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TABLE 1.—LOOSE SMUT INFECTIONS OF NEWAL BARLEY INOCULATED WITH *U. nuda* AT DIFFERENT STAGES OF OVARY DEVELOPMENT BY THE HYPODERMIC METHOD, JULY 24 AND 25, 1941

Stage of ovary at time of inoculation*	Inoculated		Uninoculated		Infection (inoculated-uninoculated) %
	Total number of plants obtained 1942	Mean infection per head %**	Total number of plants obtained 1942	Mean infection per head %	
I	207	55.6	69	4.8	50.8
II	120	44.2	69	6.9	37.3
III	212	47.6	134	0.0	47.6
IV	252	47.6	94	0.0	47.6
V	319	51.4	106	1.8	49.6
VI	422	45.3	28	7.0	38.3
VII	415	37.3	108	10.9	26.4
VIII	433	27.1	144	11.4	15.7

* Descriptions of stages are as follows: I, anthers green; II, anthers yellow but not ruptured; III, anthers ruptured; IV, pollen shedding profusely; V, after pollination; VI, approximately $\frac{3}{8}$ mature length; VII, approximately $\frac{1}{2}$ mature length; VIII, approximately $\frac{3}{4}$ mature length.

** Minimum difference of 15.1 per cent is significant beyond 5 per cent point.

High humidity was shown by Tapke (18) to increase the success of inoculations with *U. nuda.* In a study of the effect of temperature on germinating chlamydospores, Novopokrovsky and Skaskin (11) found optimum temperatures to be between 68 and 72° F. Minimum temperatures were below 41° F., and maximum temperatures from 77 to 86° F. Macrae (5) states that the optimum temperature for germination of chlamydospores is in the range 68 to 72° F. In the present study an attempt was made to determine the relation of such weather factors as relative humidity, temperature, precipitation and sunshine to infection with loose smut in the field.

MATERIALS AND METHODS

With few exceptions Newal barley (C.A.N. 1089)* was the variety used in studies of both inoculation methods and weather in relation to infection. Studies of varietal resistance to infection were conducted on material in the cereal garden. These varieties changed from year to year. Hybrids from a cross between Trebi and Glabron were also used.

Three different methods of inoculating barley with *U. nuda* have been compared. The *brush* method consists of clipping off the upper third of the lemma and applying dry chlamydospores to the stigma with a soft camel-hair brush. The *vacuum* method is similar to that described by Moore (9). The third method, hereafter referred to as the *hypodermic* method, consists of the injection of an aqueous suspension of chlamydospores through the lemma into the floret with a hypodermic syringe. The glass tube of a large hypodermic syringe capable of holding a large volume of suspension was attached. An identical method was devised independently by Poehlman (14, 15).

* Canadian Accession Number.

Chlamydospores for inoculation were procured from smutted spikes collected from varieties growing in the vicinity and stored for not more than two days before being used. The spikes were dried and crushed, and the spores sifted through a fine screen. Aqueous suspensions of 3 per cent by volume of chlamydospores were made up not more than four or five hours before use. Ovaries were inoculated just after fertilization, unless otherwise stated. A reasonably uniform stage of ovary development within the spike was insured by removing the florets on the two terminal and the basal joints of the rachis.

Percentage infection of the seeds was determined the year following inoculation. Seeds were planted at a depth of two inches. Usually a simple randomized test of one-row plots was used. Percentage infection was based on counts of smutted and normal plants, partially smutted plants being classed as smutted.

The weather data recorded at the Edmonton station of the Dominion Meteorological Service were used in this study. These data were previously found to agree with readings in the field (5). The mean daily relative humidity and temperature figures were averages of readings taken with a wet- and dry-bulb thermometer every six hours. Sunlight records were obtained with a Campbell-Stokes sunshine recorder.

RESULTS

Methods of Inoculation

The brush method of inoculation was used in 1935, 1937 and 1939, the average infections of four varieties in these years being respectively 5.2, 20.3 and 5.4 per cent (see Table 2). Because the brush method varied greatly in its effectiveness in different years, it cannot be considered a satisfactory technique of inoculation.

The vacuum method was discarded after one year's trial because of the resultant injury to the barley culms. The average infection with this method of the same four varieties above was 11.9 per cent (see Table 2).

In 1940 equal numbers of heads of seven barley varieties were inoculated using (1) the tweezer method, (2) the brush method and (3) the brush method with the head immediately being enclosed in a glassine bag. The tweezer method (19), in which chlamydospores are placed on the stigma by insertion of the tweezer points through the lemma, was superior to the others in producing infection. However, the tweezer method gave an average infection of only 6.1 per cent, which was considered to be too low to give a reliable measure of varietal resistance.

The hypodermic method of inoculation was first used in 1940, when it was compared with the brush method using Newal barley. The average infection, as determined in 1941, for the hypodermic method was 36.6 per cent, and 8.2 per cent for the brush method. The number of plants obtained from each inoculated head was 50 per cent greater utilizing the hypodermic method than by the brush method. Because of the great superiority of the hypodermic method over the brush method it was used for all inoculations in succeeding years. The data of Table 2 show the consistence with which high infections of loose smut were obtained by means of the hypodermic method.

TABLE 2.—LOOSE SMUT INFECTION (IN PER CENT) OF BARLEY VARIETIES AND HYBRIDS INOCULATED WITH *U. nuda*

Variety	Canadian accession number	Vacuum pump 1936	Method and year of inoculation							
			Brush			Hypodermic				
			1935	1937	1939	1941	1943	1944	1945	1946
Atlas	702	0.0	6.0	61.5	14.3	—	—	—	—	—
Bearer	704	5.9	79.2	68.2	5.6	48.1	—	—	—	—
Brio	876	34.5	—	15.3	0.9	23.2	—	—	—	—
Canadian Thorpe	816	0.0	—	38.1	4.6	—	—	—	—	—
Charlottetown 80	817	58.3	—	51.4	3.3	—	—	—	—	—
Chevron	1121	—	—	—	—	—	—	—	23.8	—
Colsess	772	15.2	14.9	60.0	9.9	—	85.7	—	25.4	—
Compana	1154	—	—	—	—	—	—	17.0	11.4	11.1
Donnes	115	—	—	—	—	—	—	50.3	53.2	73.2
Eureka	773	0.0	—	—	—	—	20.0	—	—	—
Glabron	718	2.4	16.3	4.2	0.7	2.9	—	—	16.2	23.7
Glacier	1149	—	—	—	—	—	—	76.7	29.9	87.7
Hannchen	837	4.7	—	27.5	4.4	—	—	—	—	—
Himalayan	765	—	0.0	—	3.3	—	18.8	—	—	—
July	720	29.2	—	7.1	0.3	37.9	—	—	—	—
Lion	86	—	—	—	—	50.3	—	—	56.5	86.5
Manchurian	726	0.0	21.7	42.3	—	—	—	—	—	—
Mensury	730	—	—	7.7	1.3	15.2	14.3	—	19.4	—
Montcalm	1135	—	—	—	—	—	44.8	55.7	24.3	48.5
Newal	1089	36.3	14.1	32.0	15.6	48.1	27.0	67.6	45.5	76.7
O.A.C. 21	1086	6.8	4.0	8.6	0.2	16.7	16.4	19.3	10.1	11.4
Olli	739	2.9	2.8	38.5	5.6	40.3	59.8	45.2	41.4	45.7
Peatland	1112	22.1	34.5	18.6	2.0	—	46.7	—	13.5	—
Plush	1106	36.7	—	8.7	9.8	46.1	67.3	91.7	38.9	77.2
Prospect	1140	—	—	—	—	—	60.5	73.6	49.0	87.0
Regal	742	0.0	12.7	—	3.1	26.2	26.8	—	27.3	66.7
Sacramento	744	—	71.9	63.9	10.7	—	—	—	—	—
Sanalta	1088	35.9	—	69.7	8.5	—	90.7	93.1	56.8	—
Titan	1164	0.0	—	0.0	0.6	0.8	4.2	0.0	1.0	0.0
Trebi	753	1.5	0.0	2.2	0.1	1.9	1.2	15.8	0.8	11.4
Tregal	1150	—	—	—	—	—	5.6	—	—	1.3
Trebi-Glabron H-29- 5	—	4.8	—	10.9	2.1	—	—	—	—	—
Trebi-Glabron H-29- 7	—	1.0	—	9.1	0.9	—	—	—	—	—
Trebi-Glabron H-29- 9	—	0.0	—	5.9	3.8	—	—	—	—	—
Trebi-Glabron H-29-10	—	0.0	—	42.9	19.9	40.4	—	—	—	—
Trebi-Glabron H-29-11	—	20.9	—	9.1	12.0	—	—	—	—	—
Trebi-Glabron H-29-12	—	0.0	—	0.0	0.0	0.0	—	—	—	—
Vantage	1162	—	—	—	—	—	—	81.4	39.6	79.2
Velvet	755	9.3	0.0	0.0	0.8	11.9	43.6	—	15.2	—
Velvon	1151	—	—	—	—	12.5	0.0	—	—	0.0
Wisc. Ped. No. 38	1101	7.7	10.4	2.3	2.5	—	—	—	15.5	79.6
Warrior	1144	—	—	—	—	—	5.5	9.0	3.8	5.1
Mean (4 varieties)*	—	11.9	5.2	20.3	5.4	26.8	28.6	37.0	24.4	36.3

* Newal, O.A.C. 21, Olli and Trebi.

Stage of Ovary Development

Preliminary inoculations with *U. nuda*, using dry chlamydospores, were made at different stages of ovary development in the years 1936, 1937 and 1938. The results indicated that inoculation during the time pollen was being shed gave higher infection than inoculation either before or after that time.

The susceptibility to infection of the ovary at eight stages of development was determined from inoculations in 1941 utilizing the hypodermic method. Descriptions of these stages are given in Table 1. Inoculations were made on sixteen heads at each stage and, as a check, uninoculated heads at the same stage of ovary development were selected. Mean infections for each stage are listed in Table 1. Stages I and V showed the highest infections among the inoculated ovaries; they were significantly higher than the two most advanced stages, VII and VIII. No significant difference is shown between stages in groups I to VI.

The susceptibility of very early stages of ovary development to injury from inoculation is indicated by the comparatively small number of plants obtained from ovaries inoculated at stages I, II, and III. These results indicate that inoculations should be delayed until ovaries are well enough developed to minimize damage, and yet early enough to give a high infection. This stage obtains from pollen dehiscence to shortly after fertilization.

Lemma and Palea Adherence

To determine whether the degree of opening of the floret after flowering affected the resistance to loose smut, inoculation was performed using the brush method on clipped and intact florets of a number of varieties growing in the field. The florets on one side of each head were clipped and those on the other side were left intact. Then dry chlamydospores were dusted into the florets with a camel-hair brush. The average infections for clipped and intact florets were the same, namely, 5.4 per cent. Dry weather at the time of inoculation was probably responsible for the low levels of infection.

Varieties

Infections of barley varieties over a number of years following inoculations with *U. nuda* are shown in Table 2. In different years a variety often varied considerably in apparent relative susceptibility, even when the same method of inoculation was used. This variation was probably caused by different weather conditions in the few days following inoculation (see next section), particularly when the brush method of inoculation was employed. It is possible that some of the year-to-year variation may have been due to changes in the locally gathered inoculum.

No marked differences in infection between rough- and smooth-awned varieties, between two- and six-rowed varieties, or between any other pair of easily defined groups are evident. The most resistant varieties were Trebi and Titan, closely followed by Warrior. Common varieties that showed a slight degree of resistance were Glabron, Velvon, Wisconsin Pedigree No. 38, Regal, O.A.C. 21 and Mensury. Many common varieties—among them Newal, Sanalta, Olli, Colsess and Montcalm—were susceptible.

Comparisons of infections of Trebi and Glabron with infections of seven smooth-awned selections from a cross of these varieties are available in Table 2. Unfortunately, inoculations were made by means of the vacuum and brush methods, with the result that infections were low and variable with the different years. However, the selections varied from extreme susceptibility to apparent immunity. The transgressive segregation for a greater susceptibility and resistance than that of the parents indicates dissimilar factors for resistance in Trebi and Glabron.

Weather Conditions

In 1939 records of humidity, precipitation, temperature and sunlight were obtained over the period during which inoculations were made. The inoculations, using the brush method, were made between 8.00 and 9.00 a.m. over a period from July 1 to August 7. Infections, of course, were determined the following year. The data lend themselves fairly well to correlation analyses, although there were no extremes recorded for any of the weather factors, and there was a rather heavy concentration of low values for infection. Correlation analyses were carried out employing the methods outlined by Goulden (3). Percentage infection was used as the dependent variable throughout.

Table 3.—Relation between infection with loose smut (i) and each of the following weather factors: humidity (h), precipitation (p), temperature (t), and sunshine (s) as measured by simple, partial and multiple correlation coefficients

Correlation coefficient	Period after inoculation				
	1 day	2 days	3 days	4 days	5 days
Simple					
r_{ih}	0.436*	0.631**	0.727**	0.781**	0.796**
r_{ip}	0.494**	0.622**	0.756**	0.792**	0.772**
r_{it}	−0.191	−0.227	−0.274	−0.306	−0.306
r_{is}	−0.327	—	—	—	—
Partial					
$r_{ih.p}$	0.179	—	—	0.491**	—
$r_{ih.t}$	0.411*	0.619**	0.716**	0.764**	0.783**
$r_{ih.s}$	0.305	—	—	0.568**	—
$r_{ih.pts}$	—	—	—	0.376	—
$r_{ip.h}$	0.311	—	—	0.505**	—
$r_{ip.t}$	0.464*	0.603**	0.735**	0.768**	0.745**
$r_{ip.s}$	0.408*	—	—	0.620**	—
$r_{ip.hts}$	—	—	—	0.469*	—
$r_{it.s}$	0.043	—	—	0.451*	—
$r_{it.hps}$	—	—	—	0.387*	—
$r_{is.h}$	−0.021	—	—	−0.258	—
$r_{is.p}$	−0.125	—	—	−0.271	—
$r_{is.hpt}$	—	—	—	−0.306	—
Multiple					
$R_{i.hp}$	0.518*	—	—	0.846**	—
$R_{i.hpts}$	—	—	—	0.867**	—

* Significant beyond the 5 per cent point.
** Significant beyond the 1 per cent point.

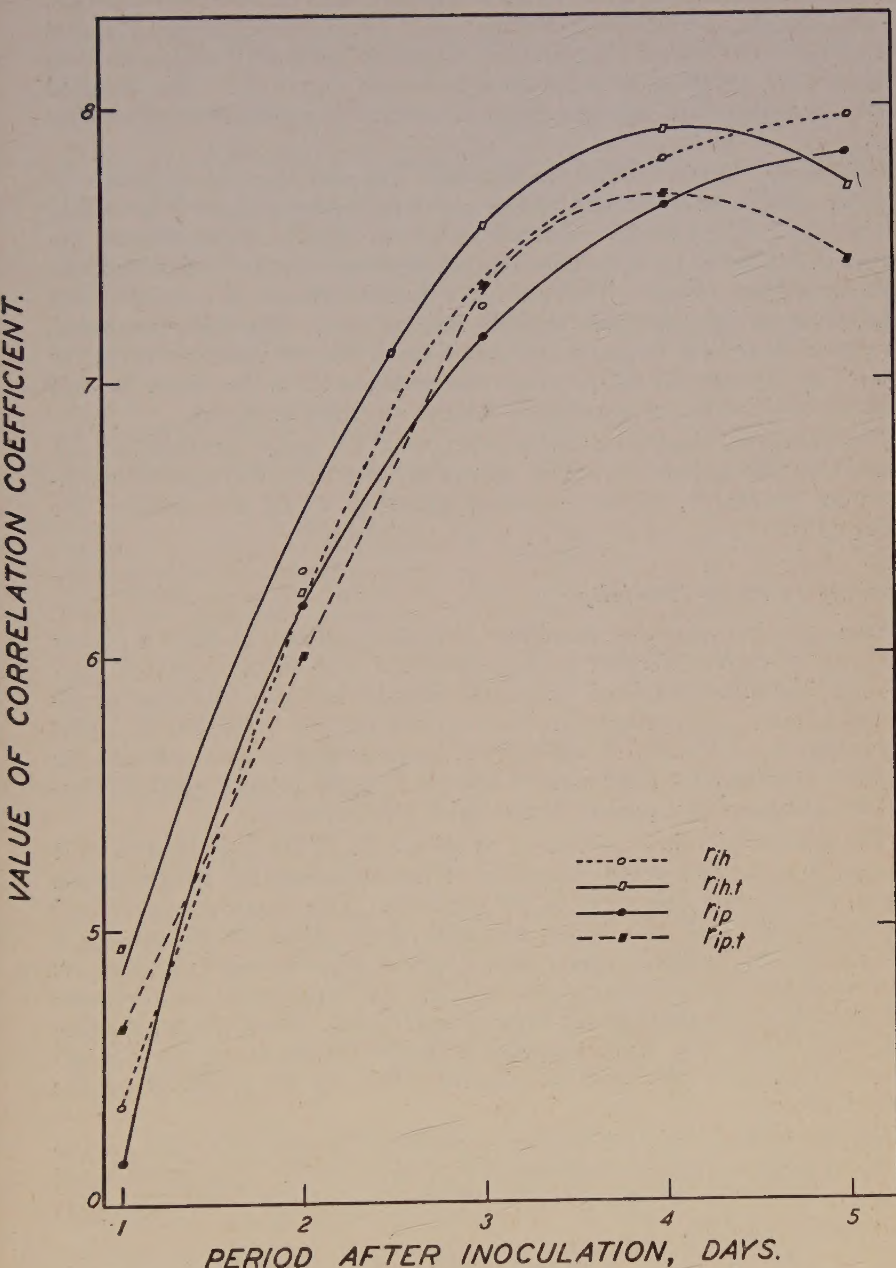

FIG. 1. Effects of length of time after inoculation on the values of correlation coefficients

The various correlation coefficients are presented in Table 3. A few analyses were carried out using average weather data for one-, two-, three-, four- and five-day periods after inoculation. There was a marked increase in the correlation values up to the four-day period but little if any advantage was gained by applying data for five days (see Figure 1). The detailed analyses were therefore carried out with four-day averages for each weather factor.

Obviously, humidity and precipitation had the greatest influence on infection. These two weather factors are closely related, and it is readily seen that their effects on infection were also associated. Nevertheless, the value of 0.846 for $R_{i.hp}$ is significantly greater than either of the component simple correlation values. This indicates that the effects of humidity and precipitation on infection are partially independent. On the other hand, the value of 0.867 for $R_{i.hpts}$ is not significantly higher than the value for $R_{i.hp}$. The inclusion of temperature and sunlight data, therefore, did not give additional information as to the factors affecting infection.

Temperature, considered independently of the other weather factors, appeared to affect infection. The results suggest that, if moisture conditions were favorable, higher levels of infection would be obtained on warmer days.

Artificially Increased Humidity

Since precipitation and humidity have been shown to have a highly significant effect on infection with *U. nuda*, it was thought that a high degree of humidity obtained artificially should increase infection of inoculated florets. Accordingly, a canvas enclosure was built around a plot of Newal barley. Relative humidities of between 90 per cent and 100 per cent were obtained by intermittent spraying of the interior with a lawn-sprinkler and keeping a pool of water inside the enclosure.

The results of this experiment, as shown in Table 4, indicated that increased humidity increased infection of florets inoculated by the brush method, the increase being 100 to 300 per cent. The hypodermic method when compared with the brush method under these conditions, gave entirely different results. Under conditions of high humidity within the canvas enclosure, the infections obtained by the hypodermic method were lower than those obtained under natural conditions. Since no evaporation would occur from the spore suspension inside the floret, the continued presence of water might have an adverse effect on the viability of the chlamydospores.

Extremely high relative humidity caused a severe reduction in the number of seeds set after inoculation by either method. This is indicated by the small numbers of plants from each head inoculated under conditions of increased humidity.

DISCUSSION

The hypodermic method of inoculation with *U. nuda* was found equal or superior to the other methods in the following ways: ease of operation; small amount of equipment necessary; and the amount of resultant infection. Similar high infections have been recorded by Poehlman (14, 15)

TABLE 4.—LOOSE SMUT INFECTION OF NEWAL BARLEY OBTAINED FROM INOCULATION WITH *U. nuda* IN 1940 UNDER NATURAL CONDITIONS AND CONDITIONS OF ARTIFICIALLY INCREASED HUMIDITY

Method of inoculation	Humidity	Total number of plants, 1941	Mean plants per inoculated head	Infection %
Inoculated July 18 (July 18-21 mean temp. 72° F., relative humidity 68%)				
Brush	Increased*	235	14.7	72.3
Brush	Natural	251	22.8	28.7
Inoculated July 19 (July 19-22 mean temp. 68° F., relative humidity 70%)				
Brush	Increased*	353	12.6	77.3
Brush	Natural	534	18.4	15.9
Check (not inoculated)	Natural	705	28.2	2.4
Inoculated July 23 (July 23-26 mean temp. 61° F., relative humidity 75%)				
Brush	Increased*	40	4.4	65.0
Brush	Natural	104	9.5	26.9
Hypodermic	Increased	69	6.3	44.9
Hypodermic	Natural	133	12.1	69.1
Check (not inoculated)	Natural	526	32.8	3.8
Inoculated July 25 (July 25-28 mean temp. 63° F., relative humidity 71%)				
Brush	Increased*	20	3.3	80.0
Brush	Natural	202	18.4	19.8
Hypodermic	Increased*	66	8.2	21.1
Hypodermic	Natural	208	14.9	45.2
Check (not inoculated)	Natural	237	23.7	1.7

* Relative humidity increased to 90-100 per cent.

when this method was used. Infections equal to those reported here have been obtained by Shands and Schaller (16) using dry spores, the spores being puffed into the floret by squeezing a rubber bulb attached to a hypodermic needle piercing the lemma. These inoculations with dry spores were performed at Madison, Wisconsin, an area of high relative humidity. It is doubtful whether such high infections would be maintained under very dry conditions.

One criticism of the hypodermic method is that varieties exhibited considerable variation in degree of infection from year to year. The year-to-year variation was not the same with each variety; one variety would be considerably higher than its average in one year, and in the same year another variety would be considerably lower than its average. However, compared with the brush method, the hypodermic method of inoculation gave considerably less of this type of inconsistent variation in degree of infection. In almost every case the hypodermic method distinguished between those varieties that were definitely resistant to loose smut and those that were to a greater or lesser degree susceptible.

The data from this study indicate that there are probably the following four classes of resistance and susceptibility to *U. nuda:*

Highly resistant: infection averaging less than 2 per cent
Resistant: infection averaging 3 to 11 per cent
Moderately resistant: infection averaging 11 to 25 per cent
Susceptible: infection averaging more than 25 per cent.

It would appear that data averaged for three years would be necessary definitely to establish the resistance or susceptibility of varieties according to the above classes. However, infections of more than 30 per cent in any one year would seem to establish susceptibility. Other workers have set up infection classes which can be compared with those used in the present study. Shands and Schaller (16) set up five infection classes with the following percentages of infection in each: 0-3, 4-15, 16-30, 31-60, and 61-100. Their classes show slightly higher ranges of infection than in the present study, and separate the susceptible material into two categories. Only three classes were established by Poehlman (15); they are: 5 per cent and under, resistant; 5.1 to 17 per cent intermediate; and over 17 per cent susceptible. Poehlman has used lower ranges of infection than those of the present study, and has not made a distinction between a resistant and a highly resistant class.

The only variety which could be classified as highly resistant to loose smut was Titan. This variety showed more than 1.0 per cent smutted plants only in 1944 when infection was 4.2 per cent.

Among varieties classified as being resistant to loose smut there were the following: Trebi, Warrior and Velvon. Tregal was tested for only two years, but will probably be in this class. These results in general agree with those of Shands and Schaller (16), except that they found Velvon to be more susceptible than indicated in the present study.

The moderately resistant class appears to be quite definite. It includes the following varieties: Mensury, O.A.C. 21 and Glabron. The latter two varieties were found by Shands and Schaller (16) to give an intermediate amount of infection.

Susceptible varieties that are or have been grown to some extent in Canada are Newal, Olli, Peatland, Plush, Regal, Wisconsin Pedigree No. 38, Montcalm, Prospect, Sanalta and Vantage. Shands and Schaller (16) also found high percentages of loose smut in the first six of the above varieties.

The incidence of loose smut in inoculated selections from the cross Trebi × Glabron indicated transgressive segregation for resistance and susceptibility to the disease. In other words, different and non-allelomorphic genetic factors are responsible for the resistance of Trebi and Glabron to *U. nuda*. Trebi and Glabron are the parents of Titan. The high resistance of the latter variety may be due to factors for resistance which were inherited from both parents. Evidence of transgressive segregation for greater susceptibility was found in one cross by Zeiner (21). Livingston (4) and Nahmmacher (10), however, found that resistance to *U. nuda* in the crosses they studied was controlled by a single factor.

The possibility of different physiologic forms of loose smut being present in the different years, or even in the same year, should not be ruled out. If there were different forms present, none of them would appear to infect Titan, unless they were only a small proportion of the total amount of inoculum collected. There were no examples, employing the

hypodermic method of inoculation, where a variety was highly susceptible in one year and highly resistant in another year. These studies would seem to indicate either that the inoculum was fairly uniform each year, or that varieties of barley have much the same resistance or susceptibility to different physiologic forms.

The factors affecting the degree of infection during inoculation by the hypodermic method were not studied in much detail. There is still a definite need to investigate the reasons for variations present. It was noted, however, that artificially increased relative humidities of between 90 and 100 per cent reduced the amount of infection compared with that obtained under normal humidities.

Inoculation by the hypodermic method during the full flowering stage or immediately after fertilization resulted in the optimum survival and infection. This agrees with the results of most other workers (7, 10, 13, 19, 21).

The brush method of inoculation was used before the hypodermic method, and a number of studies were made to determine the factors affecting the degree of infection.

The close adherence of the lemma and palea was of little importance in determining resistance to infection. This was evidenced by similar infections among clipped and intact florets, where the clipping was done prior to inoculation. These results do not eliminate the possibility of infections being greater in those varieties in which the florets remain open a longer period of time during the flowering period. Taylor and Harlan (20) attributed higher infections in the lateral than in median florets to the longer period which the former remained open at flowering time. Though it seems probable that within a variety protection against infection may be afforded to a certain class of florets by a short period of opening, nevertheless between varieties differences in infection would be due to a more fundamental cause. Resistance to *U. nuda* probably is largely physiological in nature, as reported by Livingston (4).

Inoculations with dry chlamydospores of *U. nuda* gave poor infections unless followed by three or four days of damp, wet weather. Artificially raising the humidity to 90 to 100 per cent increased the degree of infection. If the brush method of inoculation is used, this would suggest the possibility of performing mass inoculations of breeding material under a tent where the humidity can be kept at a high level.

The limited increase in loose smut infection with increased temperature is in agreement with the results of workers determining the critical temperatures for spore germination (5, 11). During the time that weather factors were studied in relation to infection, mean daily temperatures were never above the optimum set for spore germination, though at times it dropped considerably below the optimum range. In this range, temperature effects on the susceptibility of host tissue would also seem negligible.

SUMMARY

The most successful method of inoculating barley with loose smut *Ustilago nuda* (Jens) Rostr. was to inject an aqueous suspension of chlamydospores into the floret. Best results were obtained when inoculation was carried out during the period from dehiscence of pollen to the early stages of fertilization.

When florets were inoculated with dry chlamydospores moisture was the most important weather condition affecting infection. Increased infection occurred when inoculation was followed by days with higher than average relative humidity and precipitation. If moisture conditions were favorable, higher infection was obtained on warmer days. Raising the humidity artificially to near saturation increased infection when inoculations were made with dry chlamydospores, but decreased infection when inoculations were made with chlamydospores in aqueous suspension.

Barley varieties could be identified as highly resistant, resistant, moderately resistant, and susceptible to loose smut. The degree of adherence of lemma and palea after flowering was concluded to have little effect on degree of infection.

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SUR UNE MISE AU POINT D'UNE NOUVELLE MÉTHODE POUR L'EXTRACTION DES BASES ÉCHANGEABLES DES SOLS ACIDES ET DES SOLS CALCAIRES

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La détermination des bases échangeables des sols de la province de Québec débuta en 1937. Jusqu'en 1945, l'extraction se faisait selon la méthode de Williams (1). On laisse 25 grs. de sol (10 grs. dans le cas des sols argileux) en contact de 100 cc. d'acide acétique 0.5 N durant une nuit entière. On décante dans un grand entonnoir muni d'un papier filtre. Le sol est entraîné sur le papier filtre et lavé avec des portions successives de 100 cc. d'acide acétique 0.5 N jusqu'à l'obtention d'un litre de filtrat.

En plus d'avoir une énorme quantité de liquide à évaporer, nous avons constaté une extraction incomplète, surtout dans le cas des sols argileux. Au lieu de pénétrer à travers le sol, la liqueur extractive passe entre le papier filtre et l'entonnoir.

Ces inconvénients ont également été notés par C. Peng et T. S. Chu (2). Ces deux auteurs proposent l'extraction au Soxhlet. Le sol (5.0 grs. ou 2.5 grs.) est lâchement enveloppé dans un papier filtre et introduit dans le tube à extraction. On y introduit une solution d'acide acétique 0.5 N et on chauffe durant 8 ou 9 heures, de manière à obtenir de quatre à cinq siphonnages à l'heure.

Nous avons comparé cette nouvelle méthode d'extraction avec la méthode dite de Williams. D'après les chiffres obtenus (voir tableau 1) il semble que la méthode au Soxhlet, telle que décrite par Peng et Chu (2) donnent des résultats trop faibles. De plus, il existe une différence très significative entre cette méthode et la méthode dite de Williams. Cependant, la méthode de Peng et Chu possède de grands avantages. D'abord, d'après ces deux auteurs, l'extraction s'opère à une température voisine de 70° C., dépassant jamais 75° C. De plus, la quantité de filtrat à évaporer est 10 fois moindre, ce qui a son importance pour un nombre considérable d'analyses.

Une amélioration de la méthode pour l'extraction des bases échangeables au moyen d'un Soxhlet serait très avantageuse. Le schéma I laisse voir les améliorations apportées.

L'appareil Soxhlet employé est en pyrex avec joints rodés interchangeables.

Un ballon D à fond plat de 300 cc. est surmonté d'un tube à extraction E d'une capacité de 50 cc. et d'environ 30 mm. de diamètre et d'un condensateur F.

A l'intérieur du tube à extraction E, on introduit une éprouvette N de 25 mm. de diamètre et de 11 cm. de hauteur. A la tangente du côté de l'éprouvette et de la courbure du fond, on perce le trou O pour drainer la liqueur qui tombe goutte à goutte dans l'éprouvette.

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Tableau 1.—Comparaison entre les résultats obtenus par l'extraction des bases échangeables selon la méthode de Williams et selon la méthode décrite par Peng et Chu

Numéros de laboratorire	Méthode de Williams	Méthode de Peng et Chu (Soxhlet)
19789	9.9 m.e.	7.1 m.e.
19792	11.0	7.0
19794	6.0	4.1
19796	14.9	10.2
19798	20.7	17.2
19801	13.9	10.7
19805	9.5	5.6
19807	6.7	3.5
19810	9.7	6.6
19812	12.4	10.6
19814	12.2	8.5
19817	12.2	8.7
19820	7.5	5.4
19824	15.0	15.2
19827	13.4	10.0
19829	13.9	10.0
19831	7.1	4.4
19834	18.3	14.4
19837	24.0	19.8
19840	8.5	6.0
19843	6.9	6.4
19846	19.0	15.2
19848	9.9	8.0
Total	282.6	214.6
Moyenne	12.28	9.33

MD = 2.95; σ D = 1.22; σ MD = 0.255 t (Fisher) = 11.57
pour n = 22 dégrés libres t = 2.069 à 5% et 2.807 à 1%

Cette éprouvette est chargée d'ouate sur laquelle on dépose le sol à analyser. Un papier filtre est introduit dans l'orifice pour empêcher les gouttes de la liqueur extractive de tomber directement sur le sol.

On mesure, dans le ballon D, 80 cc. d'acide acétique 0.5 N, on monte l'appareil sur une plaque électrique de 500 watts (*Fisher Heavy Duty*, 8 pouces de diamètre, au médium) et l'on chauffe durant toute la nuit (environ 16 heures) en ayant soin d'établir un courant d'eau froide dans le condensateur F.

L'extraction se fait sur 20 grs. de sol pour les terres contenant plus de 60% de sable, et sur 10 grs., pour les terres contenant moins de 60% de sable. Dans le cas d'une terre très humifère ou d'une terre noire, on emploie 4 grs. de sol humecté par quelques gouttes d'alcool.

Pour un travail en série, on peut chauffer sur une même plaque électrique de 8 pouces de diamètre, 3 appareils Soxhlet tel que décrit. On peut facilement relier deux, trois ou quatre unités et obtenir six, neuf ou douze extractions simultanées.

La liqueur acétique distille, se condense et tombe goutte à goutte sur le papier filtre, atteint lentement le sol, le pénètre intimement et se draine par l'orifice O. Aussi, le sol est-il en contact avec une solution acétique toujours fraîche. Un très fort pourcentage de cette solution se draine en passant à travers le sol et déplace les bases dites échangeables.

Après l'attaque, on transvide le ballon D dans un ballon jaugé de 100 cc. et on fait le volume. De cette quantité, 50 cc. servent à la détermination des bases échangeables, du calcium et du magnésium; 40 cc., à la détermination du potassium et 10 cc., à celle du manganèse.

TABLEAU 2.—COMPARAISON ENTRE LA MÉTHODE DÉCRITE PAR PENG ET CHU, LA MÉTHODE DE WILLIAMS ET LA MÉTHODE PROPOSÉE

Numéros du laboratoire	A	B	C
	Soxhlet (Peng et Chu)	Soxhlet (proposé)	Williams 1,000 cc.
19748	6.7 m.e.	22.0 m.e.	20.0 m.e.
19749	2.2	10.8	9.0
19750	17.8	20.1	20.0
19751	13.7	16.7	15.2
19752	17.7	21.6	18.1
19760	6.9	12.3	11.0
19761	7.5	10.0	10.9
19762	7.8	10.3	10.9
Total	80.3	123.8	115.1
Moyenne	10.03	15.47	14.39

Calcul expérimental d'après la méthode "échantillons pairés".

I. Calcul pour les expériences A et C
σ D = 4.515 σ MD = 1.596 t = 3.407
pour 7 dégés libres t = 2.365 à 5% et 3.499 à 1%

II. Calcul pour les expériences B et C
σ D = 1.469 σ MD = 0.519 t = 2.115
pour 7 dégrés libres t = 2.365 à 5% et 3.499 à 1%

D'après l'analyse statistique des résultats obtenus et compilés au Tableau 2 on peut conclure ainsi:

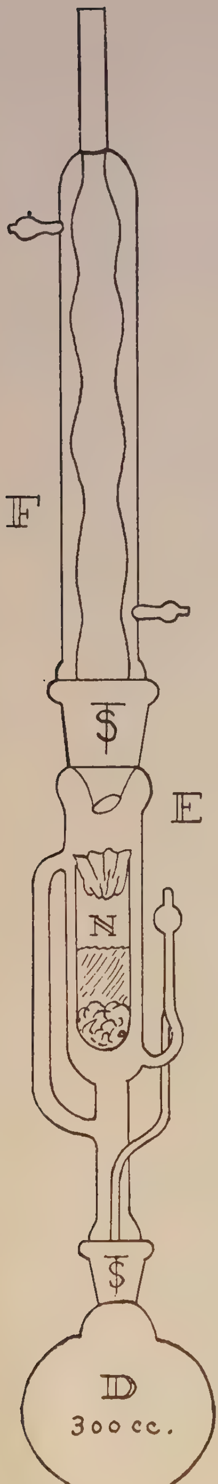
1. Il existe une différence très significative entre la méthode de Peng et Chu et la méthode de Williams, et, a fortiori, la méthode proposée, car le différence moyenne est plus grande que dans le cas de la méthode de Williams.

2. Il n'existe aucune différence significative entre la méthode proposée et la méthode de Williams.

Cependant, dans la méthode proposée, les résultats obtenus sont légèrement plus élevés. Sur un grand nombre d'échantillons, il pourrait peut-être exister une différence significative entre la méthode proposée et la méthode de Williams.

SOLS CALCAIRES

Dans le cas de sols calcaires, l'acide acétique, en plus de déplacer les cations fixés sur les colloides organiques ou minéraux, décompose les carbonates de calcium et de magnésium contenus dans le sol. Il y a dégagement de CO^2 et les ions Ca^{++} et Mg^{++} passent dans la liqueur extractive sous forme d'acétate de calcium et d'acétate de magnésium.



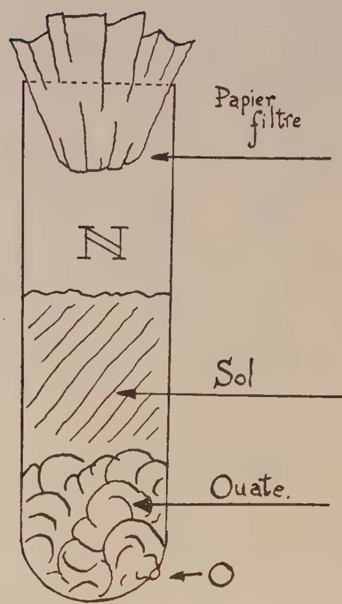


SCHÉMA 1. Schéma de l'appareil pour extraction des bases échangeables dans les sols acides.

Cette liqueur extractive contient donc les bases échangeables et les cations Ca^{++} et Mg^{++} libérés de la décomposition des carbonates. En connaissant la quantité exacte du CO^2 dégagé durant l'extraction, on peut, par différence, trouver les bases échangeables. Soit A la somme des milliéquivalents des bases échangeables et des bases provenant de la décomposition des carbonates, B la quantité, exprimée en milliéquivalent, du CO^2 dégagé et T le nombre de milliéquivalents de bases échangeables du sol, on a:

$$T^{(m.e.)} = A^{(m.e.)} - B^{(m.e.)}$$

En utilisant l'appareil Soxhlet, pour l'extraction des bases échangeables par l'acide acétique, il est facile de recueillir et de doser le CO^2 dégagé de la décomposition des carbonates. Il s'agit d'y adapter un dispositif spécial.

Le foyer à extraction est identique à celui employé dans le cas des sols non calcaires. A un Soxhlet tel que décrit plus haut (voir schéma I) on a adapté un train dans lequel passe un courant d'air (voir schéma II).

Dans le condensateur F on introduit un tube de verre très fin descendant dans le tube à extraction E, à quelques millimètres au-dessus de l'éprouvette N. Un autre tube de verre part de l'orifice du condensateur F et va dans G.

L'avant-train sert à débarrasser l'air du CO^2 qu'il contient. Il se compose d'une pipette A de 25 cc., d'une fiole conique B à suction contenant de l'acide sulfurique concentré, et de deux tubes en U, C et C^1 remplis d'ascarite on de caroxite.

L'arrière-train sert à absorber le CO^2 dégagé lors de la décomposition des carbonates par l'acide acétique. Il se compose d'une trappe de sureté G, d'un renflement H (pipette de 25 cc.), d'une bouteille I, contenant une solution de sulfate d'argent légèrement acidifiée par quelques gouttes d'acide sulfurique concentré. Cette solution sert à la fixation des vapeurs acétiques. Ainsi débarrassé de ses vapeurs acétiques, l'air continue à circuler dans un autre renflement J (pipette de 25 cc.), et vient barboter dans une solution titrée de $Ba(OH)^2$ contenue dans trois éprouvettes, K,K' et K'' de 25 mm. de diamètre et de 250 mm. de hauteur. Une autre trappe de sureté L communique à une trompe à eau. Les trois renflements A, H et J empêchent les solutions de $Ba(OH)^2$, de Ag^2SO^4 et de H^2SO^4 de siphonner. Ils absorbent, en effet, le flux occasionné par la succion provoquée lors de chaque siphonnage du Soxhlet.

Protocoles de l'extraction:

On opère de la manière décrite plus haut. On pèse 5 grs. de sol dans l'éprouvette N, on mesure 80 cc. d'acide acétique 0.5 N dans le ballon D, on monte l'appareil et on chauffe. Au même moment on branche la trompe à eau au point N du circuit et un faible courant d'air est établi. Ce courant d'air entraîne le CO^2 contenu dans l'appareil. Quant au CO_2 dissous dans l'acide acétique, il est expulsé par l'ébullition de l'acide et entraîné par le même courant d'air. Lorsque la première goutte de la liqueur extractive se condense et tombe sur le papier filtre placé dans l'orifice de l'éprouvette N (voir, schéma II) on ferme le robinet M. On

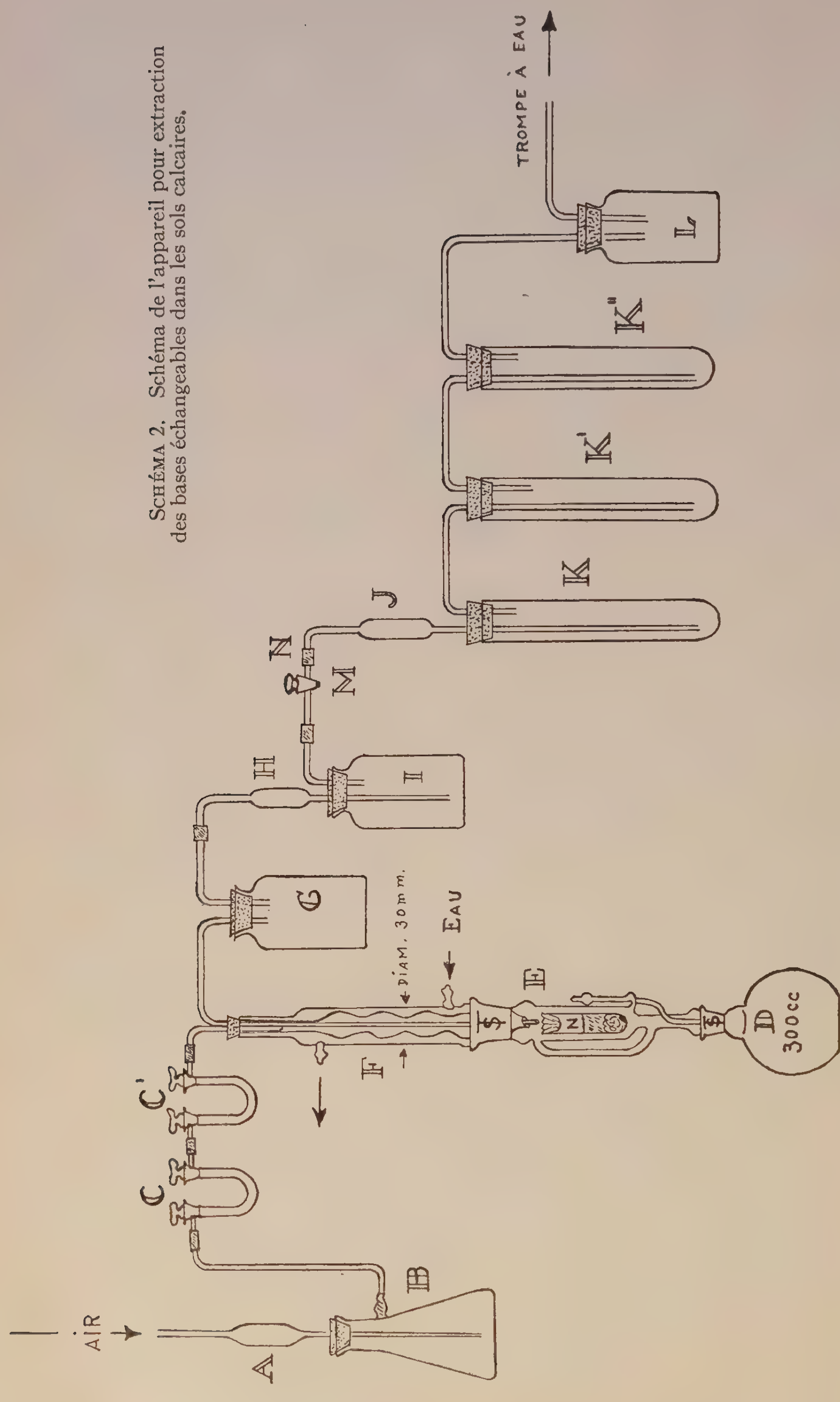


SCHÉMA 2. Schéma de l'appareil pour extraction des bases échangeables dans les sols calcaires.

attelle aussitôt la partie du train formée par les éprouvettes K, K′ et K″ contenant chacune 50 cc. de $Ba(OH)^2$ titré (normalité variant de 0.1 à 0.2) au même point N où était attelée la trompe à eau. Celle-ci est alors branchée à la trappe de sûreté L. On ouvre le robinet M et un faible courant d'air est établi dans tout le circuit. L'acide acétique décompose les carbonates du sol. Le CO^2 est entraîné par le courant d'air, barbote dans les trois éprouvettes contenant la solution de baryte et s'y fixe sous forme de carbonate de baryum. L'excès de la solution d'hydroxyde de baryum est dosé par une solution d'acide oxalique 0.1 N en présence de la phénolphtaléine. Par différence, on obtient la quantité de CO^2 dégagé de la décomposition des carbonates du sol.

On dose alors les bases contenues dans la liqueur extractive. On exprime les résultats en milliéquivalent. De ce total, on soustrait la quantité de milliéquivalents du CO^2 absorbé par la solution de $Ba(OH)^2$. La différence donne les bases échangeables du sol calcaire à analyser.

CONCLUSIONS

L'extraction des bases échangeables par la méthode proposée et décrite dans la première partie de ce travail donne des résultats plus élevés que ceux obtenus par la méthode de Peng et Chu. La différence est très significative. Dans la méthode proposée le sol est contenu dans une éprouvette de 25 mm. de diamètre, et trouée dans sa partie inférieure. Cette éprouvette est introduite dans un Soxhlet. La liqueur extractive tombe dans l'éprouvette et se draine à travers le sol. Par conséquent, l'extraction est de beaucoup plus complète que dans le cas de la méthode préconisée par Peng et Chu.

Dans la méthode proposée, l'extraction est légèrement plus forte que dans le cas de la méthode de Williams. Cependant, tout porte à croire que la différence pourrait être significative en opérant sur un grand nombre d'échantillons.

De plus, la méthode proposée possède de réels avantages sur la méthode de Williams. L'extraction se fait à une température à peu près uniforme. En outre, il y a une réelle économie d'acide acétique. Enfin, par la méthode proposée, on gagne un temps précieux. En effet, l'extraction peut se faire la nuit sans surveillance et elle livre à l'analyste les bases échangeables dans une solution concentrée (100 cc. au lieu de 1,000 cc.) ce qui simplifie les manipulations.

La méthode proposée peut aussi servir à l'extraction des bases échangeables dans les sols calcaires.

Parmi les nombreuses méthodes préconisées pour l'extraction des bases échangeables dans les sols calcaires, aucune semble donner entière satisfaction. Si l'extraction se fait, soit par une solution d'un sel neutre, soit par une solution d'un acide faible, il est toujours difficile, pour ne pas dire impossible, de calculer la quantité exacte des carbonates du sol transformés ou décomposées par ces solutions extractives. Or, dans la méthode décrite dans la deuxième partie de ce travail, on peut calculer exactement la quantité de carbonates du sol décomposés par l'action de l'acide acétique lors de l'extraction des bases échangeables. En effet, en adoptant, à

l'appareil Soxhlet, le circuit décrit plus haut, on peut recueillir dans l'hydroxyde de baryum le gaz carbonique dégagé. La quantité du CO^2 recueilli provient exclusivement du sol.

Cette méthode d'extraction des bases échangeables dans les sols calcaires a donné des résultats très satisfaisants pour un grand nombre de sols calcaires de la province de Québec.

ENGLISH SUMMARY

A comparison has been made between two methods for determining exchangeable bases in soils, and a new procedure has been proposed for acid and calcareous soils.

The extraction of exchangeable bases according to the proposed method described in the first part of this paper gives results, which are significantly higher than those obtained by Peng and Chu. In the proposed method, the soil is placed in a 25 mm. test tube with a hole at the lower part. This test tube is set into a Soxhlet. The extracting solution drops into the test tube, saturates the soil and is drained through the hole.

The proposed method can also be used for exchangeable bases extraction on calcareous soils. In previous methods used, it has been difficult to determine exactly the amount of soil carbonates converted or decomposed by the extracting solutions.

In the second part of this paper, the amount of soil carbonates decomposed by acetic acid during the extraction time is accurately determined. A train is adapted to a Soxhlet apparatus to collect the CO^2 evolved during extraction in a barium hydroxide solution.

This process seems to give satisfactory results for the determination of the exchangeable bases on the calcareous soils of the province of Quebec.

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THE CLIMATES OF CANADA ACCORDING TO THE NEW THORNTHWAITE CLASSIFICATION[1]

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Thornthwaite's new climatic classification (8) is radically different from the one that preceded it (9). The present system is based on the recognition that precipitation must be compared with water need or potential evapotranspiration. It presents a method of determining water need quantitatively and of computing actual evapotranspiration, water surplus and water deficiency. The new classification follows from the relationship between water surplus and water deficiency and is the first to be based on climatic data alone without reference to the distribution of vegetation and soils.

EVAPOTRANSPIRATION

Potential evapotranspiration is defined as the amount of water that would be transferred from the soil to the atmosphere by evaporation and transpiration if it were constantly available in optimum quantity. In his recent article, Thornthwaite points out that there is very little information on the geographic distribution of water need since it cannot be measured directly, but must be determined experimentally. However, the importance of knowing the seasonal march of water need and its distribution over the surface of the earth led to a search for a relationship between potential evapotranspiration as determined in a few localities by various means and other climatic factors for which there were abundant data. A rather complex formula was devised for computing the daily or monthly water need from the mean air temperature with a modifying length-of-day factor. With the aid of Thornthwaite's tables and nomogram, the potential evapotranspiration can be computed for any place for which there are figures of mean temperature, providing the latitude is known. Monthly or daily values of moisture surplus and moisture deficiency can also be determined by a simple bookkeeping procedure if observations of precipitation are available.

The observations that Thornthwaite used in deriving his equation for potential evapotranspiration were all made in the United States. He was not certain that the formula would work satisfactorily in polar regions. Although there are no extensive series of measurements in Canada, there is a variety of evidence that the computed values of potential evapotranspiration are here of the right order of magnitude just as they are in the United States.

A program to measure the potential evapotranspiration from a grass covered surface was initiated in 1947 in Toronto by the Ontario Research Foundation, and described in a recent publication (5). Daily measurements of the water loss from tanks growing timothy and crested wheat grass indicated that the formula gave reasonable values of water need. (See Table 1).

[1] Presented at meeting of Soils Section, Agricultural Institute of Canada, 28th Annual Meeting, Guelph, Ont., June 22, 1948.

[2] Research Fellow.

TABLE 1.—MEASURED AND COMPUTED POTENTIAL EVAPOTRANSPIRATION, TORONTO 1947 (IN INCHES)

	Tank A, timothy	Tank B, timothy	Tank C, crested wheat	Tank D, crested wheat	Computed
June (6 days)	1.0	1.0	1.1	1.1	1.1
July	4.7	5.0	4.6	4.8	5.1
August	4.3	4.7	4.6	4.8	5.3
September	3.1	3.2	3.2	—	3.4
October	1.6	1.6	1.6	—	2.4
November (14 days)	0.4	0.4	0.4	—	0.4
Total	15.1	15.9	15.5	—	17.7

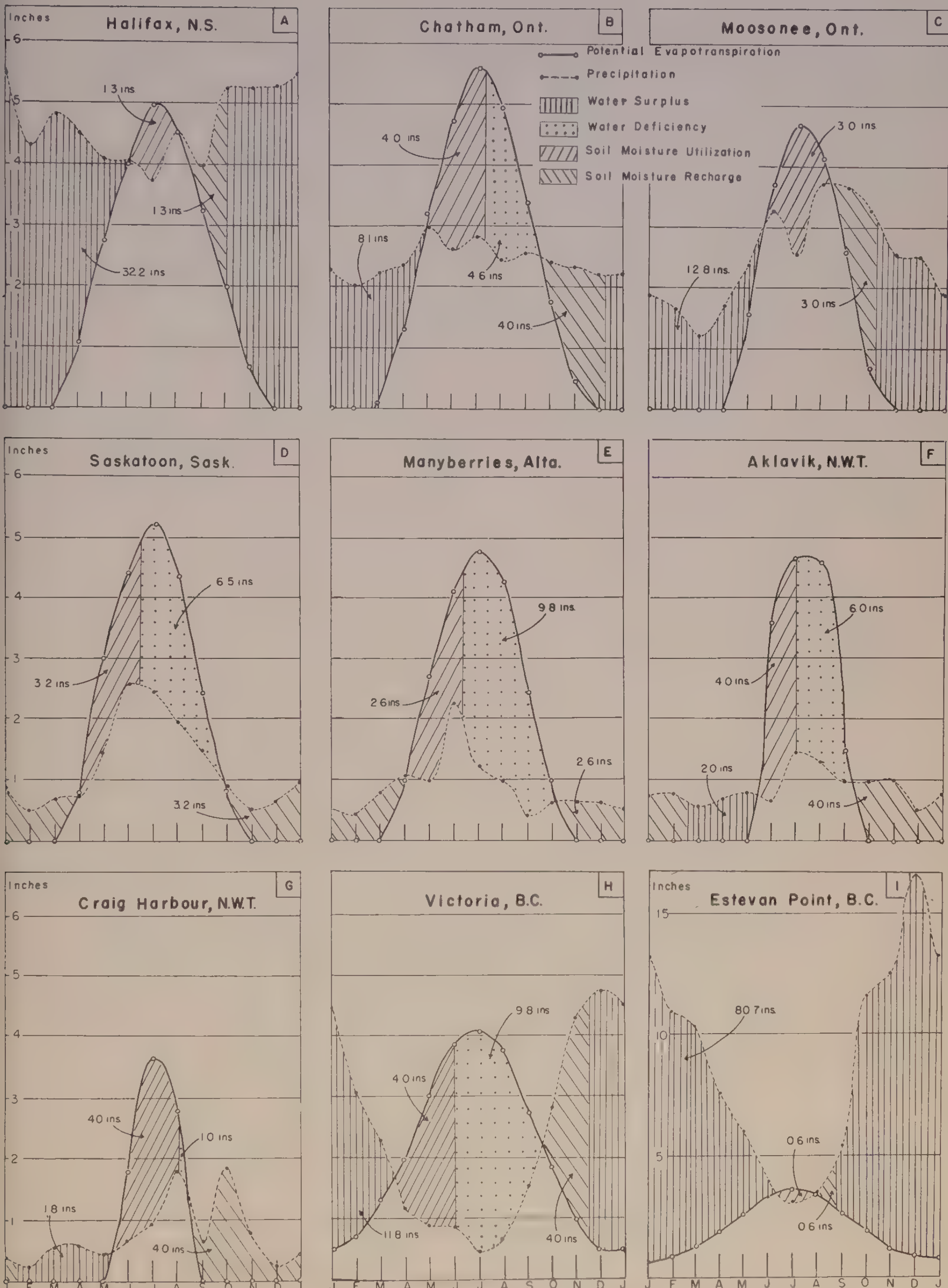
In spite of the fact that further research will doubtless result in modification of the formula, the following graphs of selected stations and series of maps which present the average values of water need, surplus, and deficiency for the whole of Canada provide new insight into the climatic differentiation of the Dominion.

GRAPHS OF SELECTED STATIONS

Graphs showing the relationship between water need and precipitation at selected stations are given in Figure 1. In Canada water need is usually zero during the winter months and rises to a peak of approximately 4 to 5.5 inches in July. Only the Pacific coast regions have water need in every month of the year. On the other hand the curve of precipitation varies widely throughout the Dominion and nowhere does it coincide with the curve of need. In most localities there is too much moisture in winter when the need is low, and too little in summer when maximum need occurs.

In Halifax (Figure 1-A) precipitation varies from 4 to 5.5 inches per month throughout the year and only in July does the need rise above that amount. The vegetation does not suffer immediately from lack of moisture, since a reserve moisture supply is stored in the soil. Although the reserve varies for different soils, Thornthwaite found that for most agricultural soils in the United States it is approximately 4 inches. This was found to be true for English soils as well (4). In Halifax, the reserve moisture stored in the soil is not exhausted before precipitation rises above need and the stored moisture is again built up to its maximum. After the maximum has been reached surface or sub-surface run off occurs. This surplus water is lost so far as the vegetation is concerned but plays an important role in the leaching of soil. For Halifax the total water surplus is 3.2 inches. The method of calculating monthly water deficiencies and surpluses is illustrated below for Halifax and Winnipeg (Table 2). Values are plotted on graphs, Figures 1-A and 7-M.

In southern Ontario precipitation is uniformly between 2 and 3 inches per month, but the need in July rises to more than 5 inches. In Chatham (Figure 1-B) for example the need rises above the precipitation in May and by mid-July the stored moisture is exhausted. From then until autumn,



Precipitation and potential evapotranspiration at selected stations

FIGURE 1

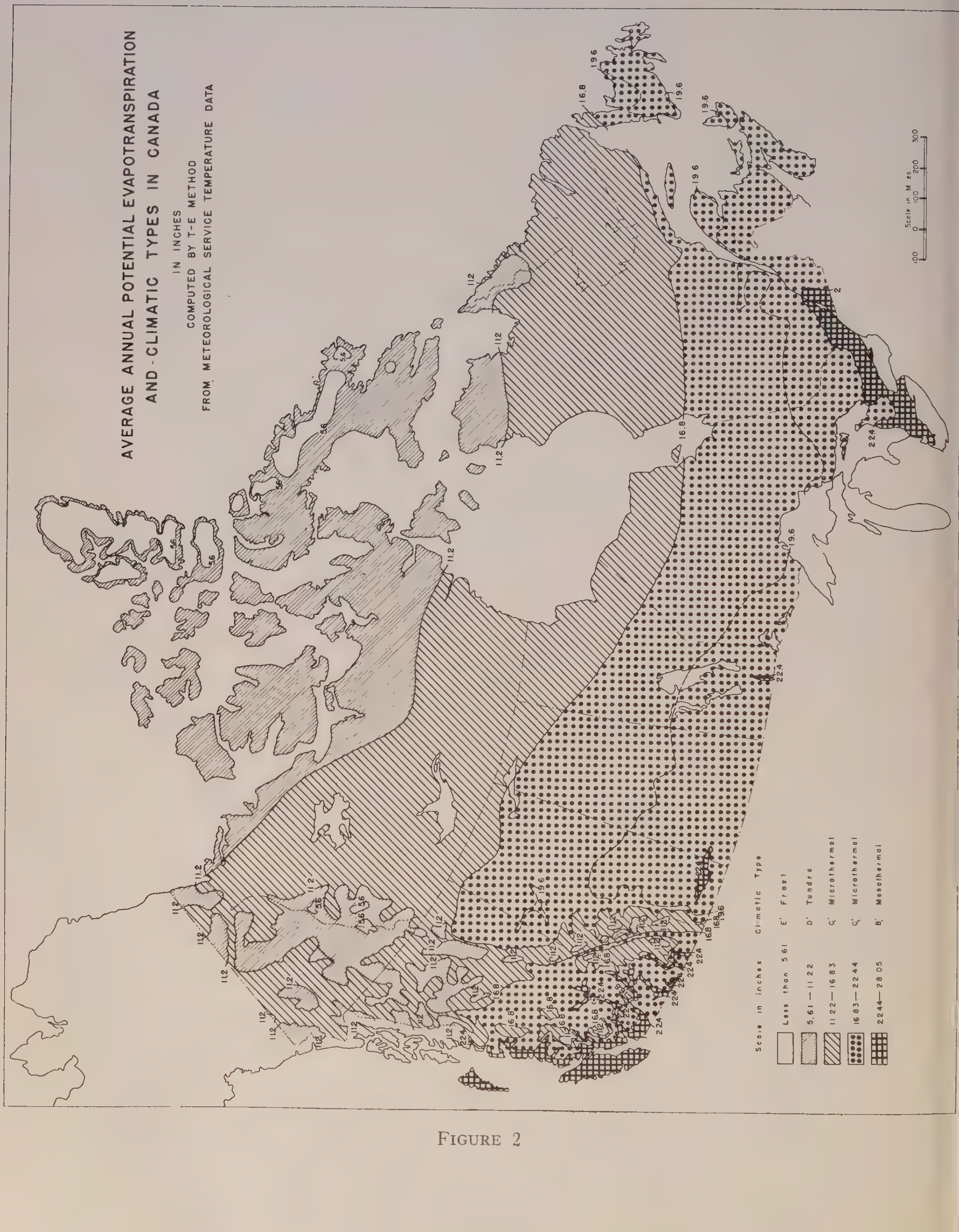

AVERAGE ANNUAL POTENTIAL EVAPOTRANSPIRATION
AND-CLIMATIC TYPES IN CANADA
IN INCHES
COMPUTED BY T-E METHOD
FROM METEOROLOGICAL SERVICE TEMPERATURE DATA
Scale in inches
Climatic Type
Less than 5.61
E' Frost
5.61 — 11.22
D' Tundra
11.22 — 16.83
C'1 Microthermal
16.83 — 22.44
C'2 Microthermal
22.44 — 28.05
B'1 Mesothermal
Scale in Miles
100 0 100 200 300

FIGURE 2

TABLE 2.—COMPARATIVE MOISTURE DATA FOR HALIFAX, N.S. AND WINNIPEG, MAN. (IN CENTIMETRES)

Halifax

	J	F	M	A	M	J	J	A	S	O	N	D	Yr.
Potential evap.	0	0	0	2.9	7.0	10.2	12.6	11.6	8.3	5.1	1.8	0	59.5
Precipitation	14.1	11.0	12.1	11.5	10.4	10.3	9.5	11.4	10.2	13.4	13.5	13.8	141.2
Storage change	0	0	0	0	0	0	0	−3.1	−0.2	1.9	1.4	0	0
Storage	10.0	10.0	10.0	10.0	10.0	10.0	6.9	6.7	8.6	10.0	10.0	10.0	—
Actual evap.	0	0	0	2.9	7.0	10.2	12.6	11.6	8.3	5.1	1.8	0	59.5
Water deficiency	0	0	0	0	0	0	0	0	0	0	0	0	0
Water surplus	14.1	11.0	12.1	8.6	3.4	0.1	0	0	0	6.9	11.7	13.8	81.7

Winnipeg

	J	F	M	A	M	J	J	A	S	O	N	D	Yr.
Potential evap.	0	0	0	1.8	7.7	11.7	14.7	11.8	6.7	2.4	0	0	56.8
Precipitation	2.3	2.2	3.0	3.5	5.7	8.0	7.8	6.2	6.0	3.8	2.8	2.4	53.7
Storage change	2.3	1.1	0	0	−2.0	−3.7	−4.3	0	0	1.4	2.8	2.4	—
Storage	8.9	10.0	10.0	10.0	8.0	4.3	0	0	0	1.4	4.2	6.6	—
Actual evap.	0	0	0	1.8	7.7	11.7	12.1	6.2	6.0	2.4	0	0	47.9
Water deficiency	0	0	0	0	0	0	2.6	5.6	0.7	0	0	0	8.9
Water surplus	0	1.1	3.0	1.7	0	0	0	0	0	0	0	0	5.8

when precipitation is again sufficient to meet the need, the plants must depend solely on current precipitation. In the Chatham district this is not sufficient and a water deficiency of 4.6 inches occurs in the average year.

At Moosonee in northern Ontario (Figure 1-C) the precipitation curve follows the curve of need more closely but during the three summer months the need is more than the current precipitation, and 3 of the 4 inches of reserve moisture are utilized. There is no water deficiency here in the average year.

Examples of precipitation regimes in the Prairie Provinces are shown in the graphs of Saskatoon (Figure 1-D) and Manyberries (Figure 1-E). Here the precipitation during the cooler months of the year, when there is no water need, is insufficient to replenish the stored moisture supply and consequently there is no water surplus and no run-off. At the beginning of the average growing season in Saskatoon there is approximately 3 inches of available water stored in the soil. About the first of July the stored moisture is exhausted, and thereafter the vegetation must depend on current precipitation. Precipitation in summer in the prairies rarely exceeds 2 inches per month but water need in July is more than 4.5 inches. The average moisture deficiency is 6.5 inches at Saskatoon and 9.8 inches at Manyberries.

At Aklavik, within the Arctic Circle (68° N.), the march of water need and precipitation resembles that of stations in the southern prairies (Figure 1-F). However, the short season of need, combined with slightly more winter precipitation, results in an average water surplus of about 2 inches. In June, the water need rises rapidly to 4.5 inches but precipitation is less than 2 inches and by mid-July the moisture reserve in the soil is exhausted. This poor distribution of moisture results in a summer water deficiency of 6 inches.

Craig Harbour at the southern tip of Ellesmere Island (76° N.) has a different type of Arctic climate (Figure 1-G). Here water need occurs only in the three summer months and the annual total is 8.3 inches. Even at this latitude the water need in July is 3.5 inches, but precipitation is only one inch, with the result that at the end of August, the stored soil moisture is exhausted and a deficiency of one inch occurs. In winter, surplus moisture amounts to almost two inches.

The two remaining graphs illustrate west coast climates. They are characterized by a winter maximum and summer minimum precipitation regime. Mean temperatures never go below freezing and there is water need in every month of the year. Estevan Point (Figure 1-I) in the west central part of Vancouver Island has an annual precipitation of 104 inches. Only in July does need rise above precipitation and then only slightly. The total amount drawn from the stored soil moisture is only 0.6 inches. For 10 months of the year precipitation exceeds water need and the average annual water surplus is 80.7 inches. Victoria (Figure 1-H) lies on the leeward side of Vancouver Island and receives 27 inches of rainfall with a distribution through the year similar to that at Estevan Point. During the winter 4.5 inches of rain falls per month when the need is 0.5 inch. The winter surplus is 12 inches. During the summer precipitation is least when need is greatest and the water deficiency amounts to approximately 10 inches.

DESCRIPTION OF THE MAPS

Maps have been prepared to show the geographic distribution of the new climatic elements in Canada together with Newfoundland and Labrador. Records of mean monthly temperature and precipitation of approximately 650 weather stations were used in the computations (1). The number of years of record included in the normals varies with the regions. Most have more than 20 years of record but for some of the far northern stations the normals include less than 10 years. Wherever possible, the normals were revised to 1939. Because of the limited number of weather records from Northern Canada and the Arctic Islands the maps of these areas are tentative and subject to revision when additional information becomes available.

POTENTIAL EVAPOTRANSPIRATION OR WATER NEED

Figure 2 shows the distribution of average annual potential evapotranspiration or water need in Canada. As defined above, the water need is the amount of moisture that would be transferred from the surface of the earth to the atmosphere if it were available. It is expressed as inches or centimeters depth of water over the area; in the same units as precipitation. Almost everywhere in Canada it exceeds the actual evapotranspiration. It serves as an index of thermal efficiency since it is derived from the mean temperature and takes into consideration the length of day.

Water need diminishes only slowly from South to North in Canada since it is largely a summer phenomenon in northern latitudes and during this season, increasing length of day northward offsets the cooling effect of latitude. Thus, while there is a difference in water need from Florida to Maine of 23 inches, the difference in Canada for a similar span of latitude, from Nova Scotia to the tip of Labrador, is only 10 inches.

The record high potential evapotranspiration in Canada is 27.5 inches at Oliver in the Columbia Valley, B.C. A close second is Pelee Island at the tip of southern Ontario. The lowest is 7.1 inches at Fort Ross on Somerset Island. The eastern coast areas have annual water needs of 20 to 22 inches, the western coast areas 24 to 26 inches. The Atlantic coast with its prevailing offshore winds is not modified by proximity to the ocean as is the Pacific coast where the prevailing westerlies are warm onshore winds.

The southern parts of the prairie provinces have higher water needs than have corresponding latitudes in Ontario and Quebec as a result of the general circulation pattern. Warm air masses from the southern States cover much of western Canada in summer, but northern Ontario is usually overlain by cooler polar air.

WATER DEFICIENCY AND WATER SURPLUS

Average water deficiency calculated for all weather stations in Canada is plotted in Figure 3. Almost half of Canada, to the east of the Manitoba-Ontario boundary, has less than 2 inches water deficiency in the average year. Too much water in spring and fall often presents agricultural problems here, yet serious summer water deficiencies do occur, reducing crop yields and creating conditions favourable to forest fires. The important agricultural area of southern Ontario has deficiencies which are surprisingly high for an area usually considered to have adequate rainfall. The southern parts of Kent and Essex counties have average water deficiencies of more than 6 inches. Average deficiencies of over 4 inches occur in Prince Edward county, the Niagara Peninsula, the Collingwood area on Georgian Bay, and in Manitoulin Island.

Throughout central Canada average deficiencies exceed 2 inches. The annual water deficiency is more than 6 inches in the southern prairies, and more than 10 inches in the semi-arid regions of southeastern Alberta and southwestern Saskatchewan. The Mackenzie valley region has an average deficiency of more than 4 inches, showing that, contrary to general belief, evaporation is high in northwestern Canada and moisture is not adequate for plant needs.

Average deficiencies of almost 20 inches occur in the interior valleys of British Columbia, and even in the Yukon the interior valleys have serious droughts in summer. Carcross has a summer water deficiency of over 8 inches. Surprisingly high summer deficiencies of 10 to 12 inches occur

on the lee of the coast range in southeastern Vancouver Island. The westward facing slopes and mountain altitudes over 4000 feet rarely suffer water deficiencies.

The map of water surplus for Canada is shown in Figure 4. According to Thornthwaite's definition, water surplus is the result of precipitation in excess of need after the soil moisture has been replenished. Surplus water may percolate through the soil as ground water recharge or it may run off the surface into the streams. Throughout most of Canada, surplus water first appears as snow and except in the coastal areas does not run off until spring. The geographic distribution of water surplus is almost the reverse of deficiency. The interior one-third of the country has a water surplus of less than 2 inches. Eastward from the Manitoba-Ontario boundary, the surplus increases rapidly and is more than 10 inches throughout Central and Southern Ontario and Quebec. In the Maritimes, water surplus varies from 15 inches in New Brunswick to almost 40 inches along the coast of Nova Scotia and Newfoundland. The largest water surpluses in Canada are found west of the Rocky Mountains. Ocean Falls on the Pacific coast (Latitude 52° N.) has the highest average annual surplus of 155 inches. High altitudes in the mountains have fairly large surpluses and conversely, water surpluses in the valleys are less than 2 inches. It is fortunate for irrigation purposes that the regions of highest water surplus are readily accessible to the high deficiency areas of southern Alberta and the valleys of British Columbia. The water surplus figures for the northwest territories seem low in view of the large areas covered by water, but drainage was greatly deranged by glaciation on the Pre-Cambrian Shield and the movement of water impeded. Furthermore, the hydrologic regime is seriously disturbed by the widespread occurrence of permafrost. However, reports show that in general water levels are low (3) and average run-off scant (6).

One of the means that Thornthwaite used to test the reliability of his determinations of potential evapotranspiration in the United States was to compare the computed water surplus with measurements of run-off from numerous watersheds in the eastern part of the country. He reported surprising agreement considering that the computed values of water surplus refer to the points of weather observation while the measured run-off is an average of entire watersheds of widely varying area (10).

There is similar close agreement between measured run-off and computed water surplus in Canada. This is even more surprising because the snow and ice of winter makes it difficult to measure both run-off and precipitation and reduces the accuracy of the measurements. Table 3 gives run-off for fifty Canadian watersheds (2) and computed water surplus at weather stations within them. The degree of agreement between the two sets of data can be determined from the table and also from the maps of run-off (Figures 5a and 5b).


AVERAGE ANNUAL WATER DEFICIENCY
IN CANADA
IN INCHES
Scale in inches
Less than 2
2 - 4
4 - 6
6 - 8
8 - 10
10 and over
Scale in Miles
100 0 100 200 300

FIGURE 3

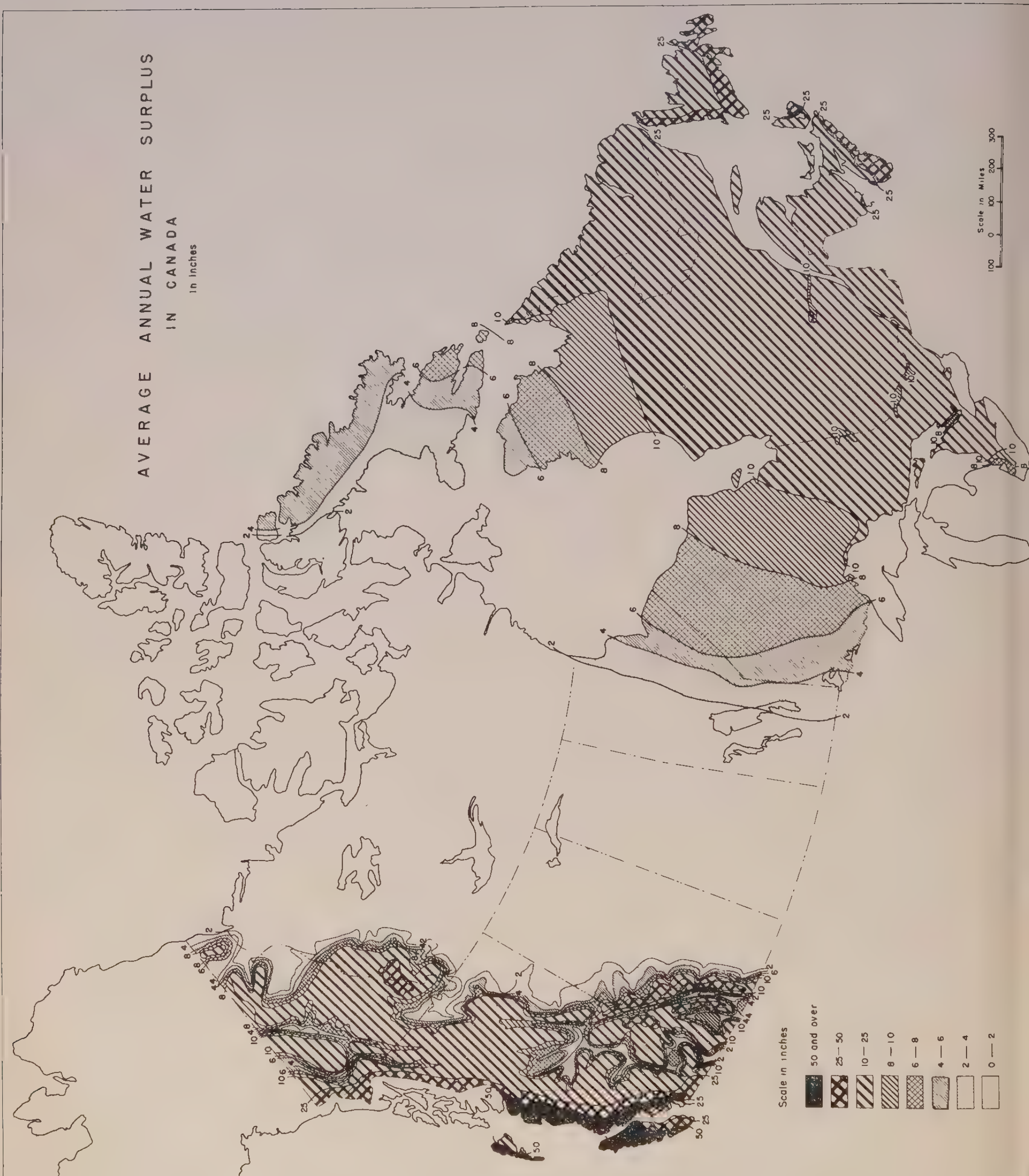

AVERAGE ANNUAL WATER SURPLUS
IN CANADA
In Inches
Scale in Inches
50 and over
25 — 50
10 — 25
8 — 10
6 — 8
4 — 6
2 — 4
0 — 2
Scale in Miles
100 0 100 200 300

FIGURE 4

TABLE 3.—COMPARISON OF MEASURED RUN-OFF AND COMPUTED WATER SURPLUS IN CANADA

St. Lawrence and Hudson Bay Drainage

Watershed	Gauging station	Area, sq. mi.	Period	Run-off (inches)	Computed water surplus (inches)
In Ontario					
1. Magpie	Steep Hill Falls	635	1919-38	15.6	Steep Hill Falls 23.7 Franz 11.9
2. Spanish	High Falls	2558	1920-39	13.7	Biscotasing 9.5
3. Sturgeon	Crystal Falls	2570	1921-39	15.5	Crystal Falls 15.4
4. Muskoka (S. branch)	Mathiasville	660	1913-39	20.4	Beatrice 18.6 Gravenhurst 15.4
5. Muskoka (N. branch)	Port Sydney	578	1914-39	20.2	Huntsville 15.0
6. Saugeen	Walkerton	850	1913-39	15.9	Durham 20.0 Mount Forest 15.6
7. Saugeen	Lower segment, Port Elgin	715	1913-39	17.0	Walkerton 16.9
8. Thames (N. branch)	Fanshawe	585	1914-39	12.2	Stratford 15.1 Lucan 13.5
9. Thames (S. branch)	Ealing	515	1914-39	12.6	Woodstock 10.9
10. Grand	Galt	1360	1912-39	11.0	Kitchener 10.4 Guelph 8.3
11. Credit	Cataract	85	1914-39	10.0	Alton 13.0
12. Moira	Foxboro	1038	1915-39	14.1	Tweed 13.5
13. Bonnechere	Castleford	935	1921-39	8.9	Renfrew 7.5 Pembroke 11.5 Clontarf 10.4
14. Madawaska	Palmer Rapids	2230	1929-39	12.6	Bancroft 12.4 Algonquin Park 12.3 Madawaska 12.0
15. Mississippi	Lower segment, Appleton	658	1918-39	11.8	Almonte 12.2
16. Kapuskasing	Kapuskasing	2607	1917-39	13.8	Chapleau 10.2 Kapuskasing 9.4
17. Abitibi	Island Falls	80.0	1928-39	16.8	Iroquois Falls 12.9 Cochrane 8.5 Timmins 8.1 Wawaitin Falls 12.8
In Quebec					
1. Bell	Senneterre	750	1915-39	21.7	Doucet 19.0
2. Rouge (lower segment)	Bell Falls	952	1918-39	28.0	Ste. Agathe 29.3 Huburdeau 16.7

(Continued on next page)

TABLE 3.—COMPARISON OF MEASURED RUN-OFF AND COMPUTED WATER SURPLUS IN CANADA—*Continued*

Watershed	Gauging station	Area, sq. ml.	Period	Run-off (inches)	Computed water surplus (inches)
Quebec (*continued*)					
3. Chateauguay	Chateauguay-Primeauville	920	1919-39	16.8	Ste. Clothilde 15.1
4. St. Francis (between Westbury and L. St. Francis)	Westbury	808	1921-39	26.2	East Angus 23.5 Thetford 19.9 Disraeli 21.4
5. Yamaska (between Farnham and Foster)	Farnham	402	1926-39 1924-39	18.3	Brome 16.7 Farnham 16.6
6. Manouan	Dam C	1253	1918-39	16.8	Lake Kempt 14.3
7. Gens-de-Terre	Cabonga	1050	1928-39	13.2	Kakabonga 15.9
8. Lievre (between Mont Laurier and Cedar Rapids Dam)	Cedar Rapids Dam	900	1924-39	16.0	Notre Dame du Laus 16.6 Mont Laurier 12.3 Bark Lake 20.7
9. North	Ste-Adele	170	1927-39	28.8	Ste. Agathe 29.3
10. Metis	Price	587	1922-39	23.3	Price 21.1
11. Metis	Outlet of Metis Lake	143	1924-39	19.4	Lac dam Metis 17.6
Atlantic Drainage (few chances of correlation)					
1. East, N.S.	St. Margaret Bay	9.8	1925-38	37.3	Halifax 32.2
2. Lahave, N.S.	West Northfield	497	1914-38	31.6	Springfield 27.4
Pacific Drainage (few chances of correlation)					
1. Lighting Creek, B.C.	Wingdam	91	1937-40	24.8	Barkerville 19.7
2. Deep Otter Creek, B.C.	Vernon	80	1934-42	3.2	Vernon 2.8 Vernon (Coldstream River) 1.8
Arctic and Western Hudson Bay					
1. Brokenhead	Beausejour, Man.	594	1912-43	4.0	Oakbank 2.4 Winnipeg 2.3
2. Namakan	Outlet of Lac la Croix, Ont.	3425	1920-43	7.4	Atikokan 5.4 Kawene 5.8
3. Turtle	Mine Centre, Ont.	1880	1914-43	8.3	Mine Centre 6.3
4. English	Umpreville, Ont.	2465	1921-43	9.5	Ignace 11.9
5. Wabigoon	Quibell, Ont.	2490	1913-43	7.8	Dryden 5.4

(Continued on next page)

TABLE 3.—COMPARISON OF MEASURED RUN-OFF AND COMPUTED WATER SURPLUS IN CANADA—*Continued*

Arctic and Western Hudson Bay (con.)

Watershed	Gauging station	Area, sq. mi.	Period	Run-off (inches)	Computed water surplus (inches)
6. Pembina	Manitou, Man.	2060	1920-43	0.6	Morden 1.9 Swan Lake 0.4
7. Roseau	Caribou, Minn.	1530	1928-43	2.0	Sprague 2.1
8. Rat	Otterburne, Man.	704	1911-43	2.1	Morris 1.1
9. Seine	Prairie Grove, Man.	495	1915-43	2.1	Winnipeg 2.3
10. Souris	Estevan, Sask.	4760	1910-43	0.1	Estevan 0 Yellow Grass 0
11. Moose Mountain Creek	Oxbow, Sask.	1900	1912-43	0.2	Carlyle 0.6
12. Stimson Creek	Pekisko, Alta.	77	1911-43	6.0	Pekisko 3.6
13. Sevenpersons Creek	Medicine Hat, Alta.	744	1912-43	0.3	Manyberries 0
14. N. Saskatchewan (between Prince Albert and Edmonton)	Prince Albert Edmonton	35,605	1910-43	0.4	(See Map)
15. Churchill	Island Falls, Sask.	71,000	1928-43	4.0	Island Falls 3.0 Lac la Ronge 1.3
16. Beaver	Barnes Crossing, Sask.	7551	1933-40	0.9	Iron River 0 Loon Lake 0.7
17. Lesser Slave	Slave Lake, Alta.	5370	1914-40	3.9	Grouard 1.0
19. Maple Creek	Meneley's Farm, Sask.	360	1915-39	0.8	Maple Creek 0 Klintonel 0.4

THE MOISTURE PROVINCES OF CANADA

Thornthwaite's new moisture regions are rational, since their limits are derived from the climatic data themselves without reference to other factors such as vegetation and soils. The indices are based on the relation between water deficiency and surplus and water need. The ratio of water deficit to water need forms an index of aridity; the ratio of water surplus to water need forms a humidity index. Thornthwaite's moisture index is obtained by subtracting six-tenths of the aridity index from the humidity index. With an index of zero, the climate is neither moist nor dry. Positive indices denote moist climates, where water surpluses are more important than water deficiencies. Negative indices mean dry climates where

deficiencies are more important than surpluses. Moist climates may be perhumid, humid or moist subhumid; dry climates may be dry subhumid, semi-arid or arid, as follows:

	Climatic type	Moisture index
A	Perhumid	100 and above
B_4	Humid	80 to 100
B_3	Humid	60 to 80
B_2	Humid	40 to 60
B_1	Humid	20 to 40
C_2	Moist subhumid	0 to 20
C_1	Dry subhumid	0 to -20
D	Semi-arid	-20 to -40
E	Arid	-40 to -60

There are four subdivisions of the humid climates, which, unfortunately, have no individual names. The perhumid climates are not similarly subdivided although it could be possible to do so since moisture indices can be greater than 100.

Figure 6 shows the moisture regions of Canada. The limits of the moisture provinces appear as north-south lines with no evidence of the east-west zonation through central Canada that appears in other climatic and vegetation maps. The most important boundary is the O isopleth which divides the areas of predominant water surplus from those of predominant water deficiency. It extends from eastern Manitoba on the United States border to the Arctic Ocean west of Coppermine dividing the mesothermal, microthermal, tundra and frost climates alike into a moist and a dry province. To the east of the line climates are moist; to the west, as far as the Rockies, they are dry.

In Canada perhumid climates with large water surpluses and small deficiences are more extensive than in the United States. They include a large section of eastern and central Quebec, the greater part of Labrador, most of Newfoundland, the highlands of New Brunswick and the eastern half of Nova Scotia. There is a small area of perhumid climate to the east of Lake Superior in Ontario. The Pacific coast areas as far east as the crests of the coast range, and most of Vancouver Island, belong to the perhumid region. Here some extremely high P.E. indices occur. Estevan Point has an index of 334 and Ocean Falls an index of 636. Perhumid climates also characterize high altitudes in the Rockies. Two examples of perhumid climates are shown in the graphs of Halifax and Estevan Point. (Figures 1-A and 1-1).

The moisture index of 100 divides the humid from the perhumid climates. Humid climates cover most of Ontario, a large part of Quebec, much of the Maritime Provinces and the eastern part of Baffin Land in eastern Canada. Southern Ontario, often considered to have fairly uniform moisture conditions, is divided into four humid and one subhumid climatic types. In Western Canada, humid climates occur in the mountains of British Columbia and on the east cost of Vancouver Island. The humid B climates are not differentiated in the mountainous regions. Durham, Ontario (Figure 7-J) is an example of the B_4 climatic type.

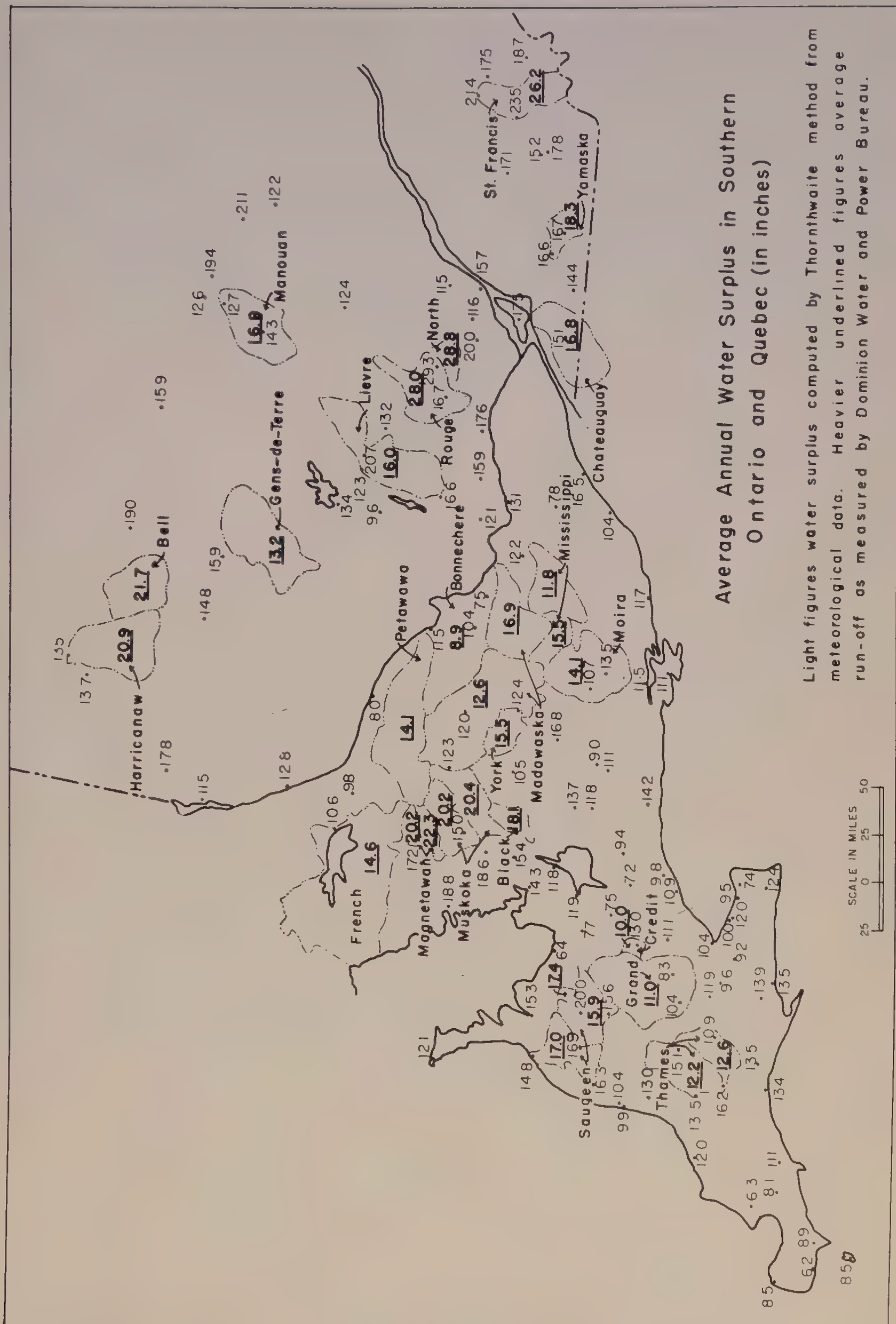

Average Annual Water Surplus in Southern Ontario and Quebec (in inches)
Light figures water surplus computed by Thornthwaite method from meteorological data. Heavier underlined figures average run-off as measured by Dominion Water and Power Bureau.
SCALE IN MILES
25 0 25 50

FIGURE 5a

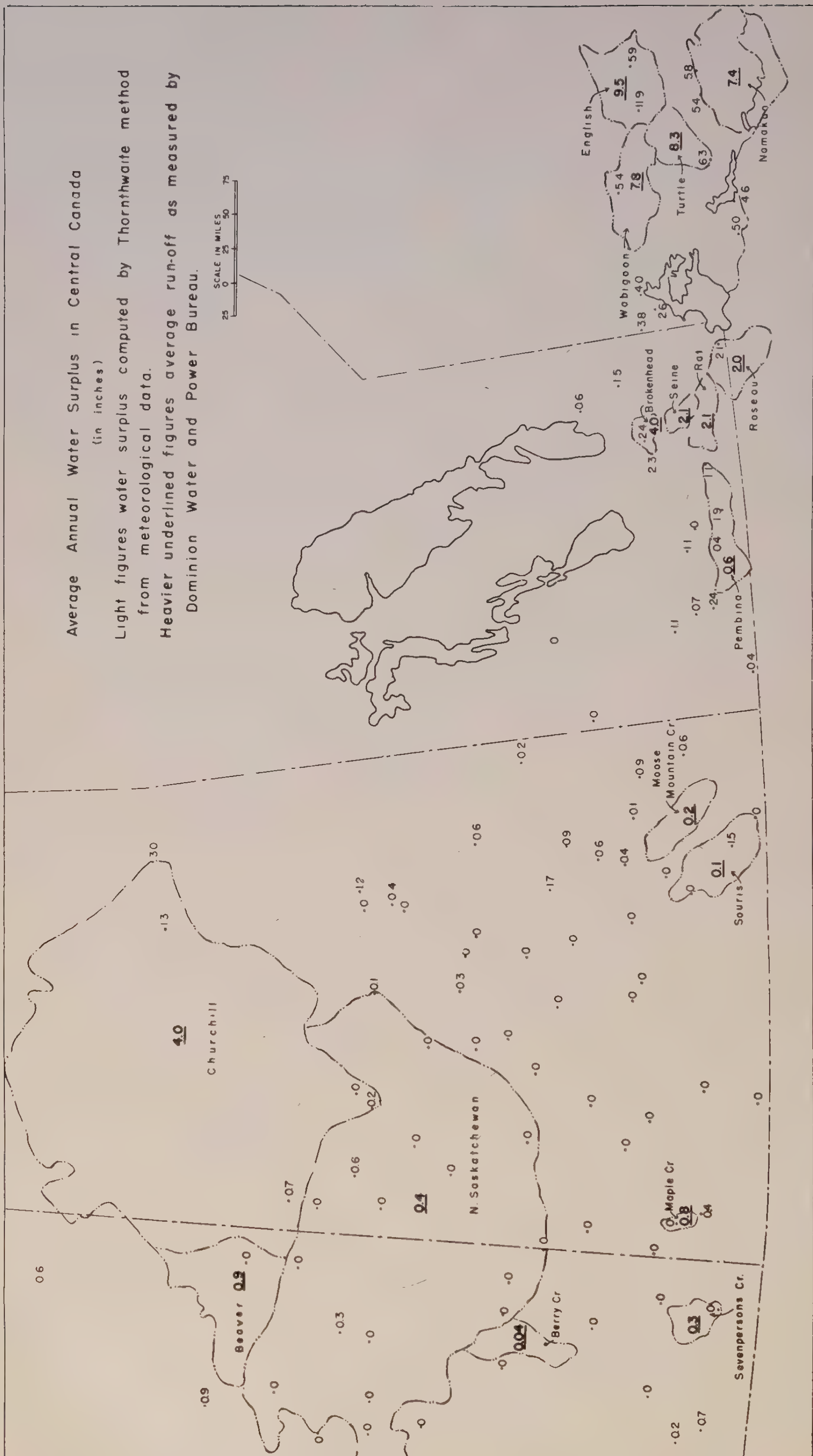

Average Annual Water Surplus in Central Canada
(in inches)
Light figures water surplus computed by Thornthwaite method from meteorological data.
Heavier underlined figures average run-off as measured by Dominion Water and Power Bureau.
SCALE IN MILES
Churchill
N. Saskatchewan
Beaver
Berry Cr
Maple Cr
Sevenpersons Cr.
Moose Mountain Cr.
Souris
Pembina
Brokenhead
Seine
Rat
Roseau
Wabigoon
English
Turtle
Namakan

FIGURE 5b

Moosonee (Figure 1-C) and Roberval, Quebec (Figure 7-K) are examples of B_3 and B_2 climatic types, respectively. Chatham, Ontario (Figure 1-B) shows B_1 climatic conditions.

Subhumid climates are very extensive. They characterize all the central part of Canada, divided by the zero isopleth into moist and dry subhumid provinces. The foothills of the mountains in British Columbia and the Northwest Territories are largely subhumid. Two stations as far apart as Winnipeg, Manitoba and Craig Harbour, N.W.T. have similar moist subhumid climates, although the water need at Winnipeg is 22 inches, and at Craig Harbour 8 inches (Figures 7-M and 1-G). Two small but interesting areas of moist subhumid climate are the extreme southwestern tip of Ontario, of which Harrow (Figure 7-L) is an example; and the southeastern end of Vancouver Island (see Victoria, Figure 1-H). Supplementary water for crops would obviously be desirable here in a majority of years.

The Prairie Provinces, the Mackenzie Valley, the interior valleys of British Columbia and the Yukon are mostly dry subhumid. Summer droughts are expected in the Prairies and the British Columbia valleys, and recent reports of crop production in the Mackenzie and Yukon valleys indicate that here too drought constitutes the chief factor limiting agricultural production (6). Saskatoon, Sask. (Figure 1-D) and Aklavik, N.W.T. (Figure 1-F) are two examples of the dry subhumid climatic type.

Canada's semi-arid climatic province is not large in comparison with that of the United States. It consists of a roughly triangular area in southern Saskatchewan and Alberta. Here average water deficiencies are large and impose serious limitations on agriculture. Figure 1-E shows the average conditions at Manyberries, Alta. However, the moisture supply varies greatly, and in some years, it is sufficient to produce good yields. This yearly variation can be determined for any station by using the year to year rather than the average figures of temperature and precipitation. Semi-arid climates are also typical of parts of the intermontane valleys in British Columbia.

Only two currently reporting weather stations in Canada have arid climates. They are Tranquille, near Kamloops on the Thompson River, and Oliver on the Okanagan River in British Columbia. Sagebrush is common at Tranquille (7). Figure 7-N indicates the average moisture conditions at Oliver, the most arid reporting station in the Dominion. In such regions agriculture is possible only with irrigation.

SEASONAL VARIATION IN EFFECTIVE MOISTURE

According to the new Thornthwaite classification, the ideal climate for crop growth would be one in which precipitation exactly followed water need, and there were no water surplus or water deficiency. There is no such climate in Canada; Thornthwaite says that no such climate exists anywhere. The closest approximation in Canada is Kenora in Western Ontario with a winter water surplus of four inches and a summer water deficiency of only 0·8 inches. It belongs to the B_1 humid climate type. Moist climates imply water surplus, but the index A, B or C_2 does not indicate whether there is a water deficiency in summer, and, if so, the magnitude of that deficiency. To humid climates, with little or no summer

deficiency, Thornthwaite has added the symbol r. If the summer deficiency is moderate in moist climates, the symbol s is added; if it is large, the symbol is s_2. These symbols are defined in terms of the aridity index as follows:

Moist climates A B C_2	Aridity index
Little or no water deficiency r	0 — 16·7
Moderate summer deficiency s	16·7 — 33·3
Large summer deficiency s_2	33·3 +

Similarly, for dry climates it is important to know if there is a water surplus in winter and the magnitude of such surplus. The following table gives the symbols for dry climate defined in terms of the humidity index:

Dry climates C_1 D E	Humidity index
Little or no water surplus d	0 — 10
Moderate winter surplus s	10 — 20
Large winter surplus s_2	20 +

The symbols s and s_2 although defined differently for the moist and dry climates, refer to the same thing for both, that is, the time of year when rainfall is most deficient.

Figure 8 shows the seasonal variation in effective moisture in Canada. Most of the regions with moist climates have little or no water deficiency. Consequently the symbol of seasonal variation is r for the greater part of Canada. In southern Ontario there are a few small sections with a moderate summer water deficiency s. In the north, Coppermine has a moist subhumid climate with a moderate summer water deficiency making it an s type. In British Columbia and the Yukon the perhumid and humid climatic types are predominantly r. An exception is the eastern part of Vancouver Island and the adjacent mainland where there is a moderate summer deficiency. The area around Victoria has a large summer water deficiency and consequently an s_2 climate.

The dry climates of central Canada are predominantly type d with little or no winter water surplus. Aklavik is an exception with a moderate winter water surplus s. Most of the arid and semi-arid valleys of British Columbia have a moderate surplus s while some have a large winter surplus s_2. This valuable surplus water is stored in reservoirs and used for irrigation during the summer dry period.

AN INDEX OF THERMAL EFFICIENCY

As Thornthwaite points out, potential evapotranspiration is an index of thermal efficiency since it is an expression of day length as well as of temperature. It is not only a growth index but expresses growth in terms of the water needed for growth. He divides the thermal climates into megathermal, mesothermal, microthermal, tundra and frost on the following basis:

TE index (or potential evapotranspiration) Cm.	In.	Climatic type	
		E′	Frost
14·2	5·61		
		D′	Tundra
28·5	11·22		
		C'_1	
42·7	16·83		Microthermal
		C'_2	
57·0	22·44		
		B'_1	
71·2	28·05		
		B'_2	Mesothermal
85·5	33·66		
		B'_3	
99·7	39·27		
		B'_4	
114·0	44·88		
		A′	Megathermal

The megathermal climates do not occur in Canada. The mesothermal type has four divisions, but only the coolest, B_1 type with a potential evapotranspiration from 22·44 to 28·05 inches is found in Canada (Figure 2).

In Eastern Canada, the southern parts of Ontario and Quebec have mesothermal climates but no currently reporting station in the Maritimes has a B′ climate. On the Pacific Coast, the type prevails at least as far as 57° 36′ N. latitude (Alaska) and includes Vancouver Island and the interior valleys of British Columbia. A small area in southern Manitoba and another in southern Alberta and Saskatchewan also belong to this climatic type. Figure 7-O shows three examples of mesothermal climates in Canada.

Microthermal climates are the most extensive in Canada, stretching from Southern Ontario to the Arctic Ocean. The isopleth of 16·8 inches potential evapotranspiration divides the microthermal climates into cooler and warmer sections. The southern half of Quebec, the Maritimes, most of Ontario and most of the Prairie Provinces belong to the warm section. Figure 7-P shows two examples of warm microthermal climates. The cooler type of microthermal climate is typical of the northern part of the Dominion with an extension down the sides of the Rocky Mountains to the United States border. The march of potential evapotranspiration at two cold microthermal stations is seen in Figure 7-R.

Tundra climates characterize nearly all the Arctic Islands, as well as the northern rim of the mainland. The areal extent of this vegetation type is shown on many maps but the Thornthwaite method provides the first opportunity of defining tundra climate in terms of the water needs of the vegetation. A tundra climate implies that the thermal efficiency is not sufficient to produce trees; it tells nothing of the moisture relationships. In tundra climates there may be sufficient moisture to supply the need or there may not be. Examples of the two types of tundra are seen in Figure

7-S. Fort Ross has a humid tundra climate with ample moisture during the short summer to supply the water need. No moisture deficiency occurs, but 5·3 of the 12 inches precipitation is surplus moisture. Bache Peninsula (Latitude 79° N.) has a dry tundra climate. Here the annual precipitation is only 5·2 inches and the water need is 9·0 inches. There is no water surplus and a 3·9 inch water deficiency occurs during the summer. None of the currently reporting weather stations in the mountains has a tundra climate. Barkerville (Latitude 52° N.) at 4180 feet reports a water need of 17·7 inches, the lowest in the southern part of British Columbia. Undoubtedly the higher altitude regions have annual water needs of less than 11·2 inches, and corresponding tundra climates.

The available records of the northern weather stations do not include any frost climates, with less than 5·6 inches potential evapotranspiration. Fort Ross with a yearly average of 7 inches is the lowest on record. The interior of Ellesmere Island and high altitudes in Baffin Land probably do have frost climates, and they are shown as such on Figure 2. In these regions, temperatures, of course, are not always below freezing but since frost inhibits vegetative growth, water leaves the surface principally by evaporation and sublimation. Frost climates also may be either humid or dry.

SUMMER CONCENTRATION OF THERMAL EFFICIENCY

The index of thermal efficiency gives the annual water need for any station but it does not state when this water need takes place. In tundra climates, 100 per cent of the annual water need occurs during the three summer months. Southward, the ratio decreases until at the equator where there are no seasons, only 25 per cent of the water is needed in any three-month period. Canada, lying as it does in the northern latitudes, receives the greatest proportion of its thermal efficiency in summer. Only a small area on the Pacific coast receives less than half the annual total in summer. Figure 9 shows the summer concentration of thermal efficiency in Canada. According to the Thornthwaite classification, for each temperature efficiency type there is a characteristic summer concentration as illustrated below.

Potential evapotranspiration	T-E type	Summer concentration percentage	Summer concentration types
inches			
	A′		a′
44·88		48·0	
	B'_4		b'_4
39·27		51·9	
	B'_3		b'_3
33·66		56·3	
	B'_2		b'_2
28·05		61·6	
	B'_1		b'_1
22·44		68·0	
	C'_2		c'_2
16·83		76·3	
	C'_1		c'_1
11·22		88·0	
	D′		d′
5·61			
	E′		

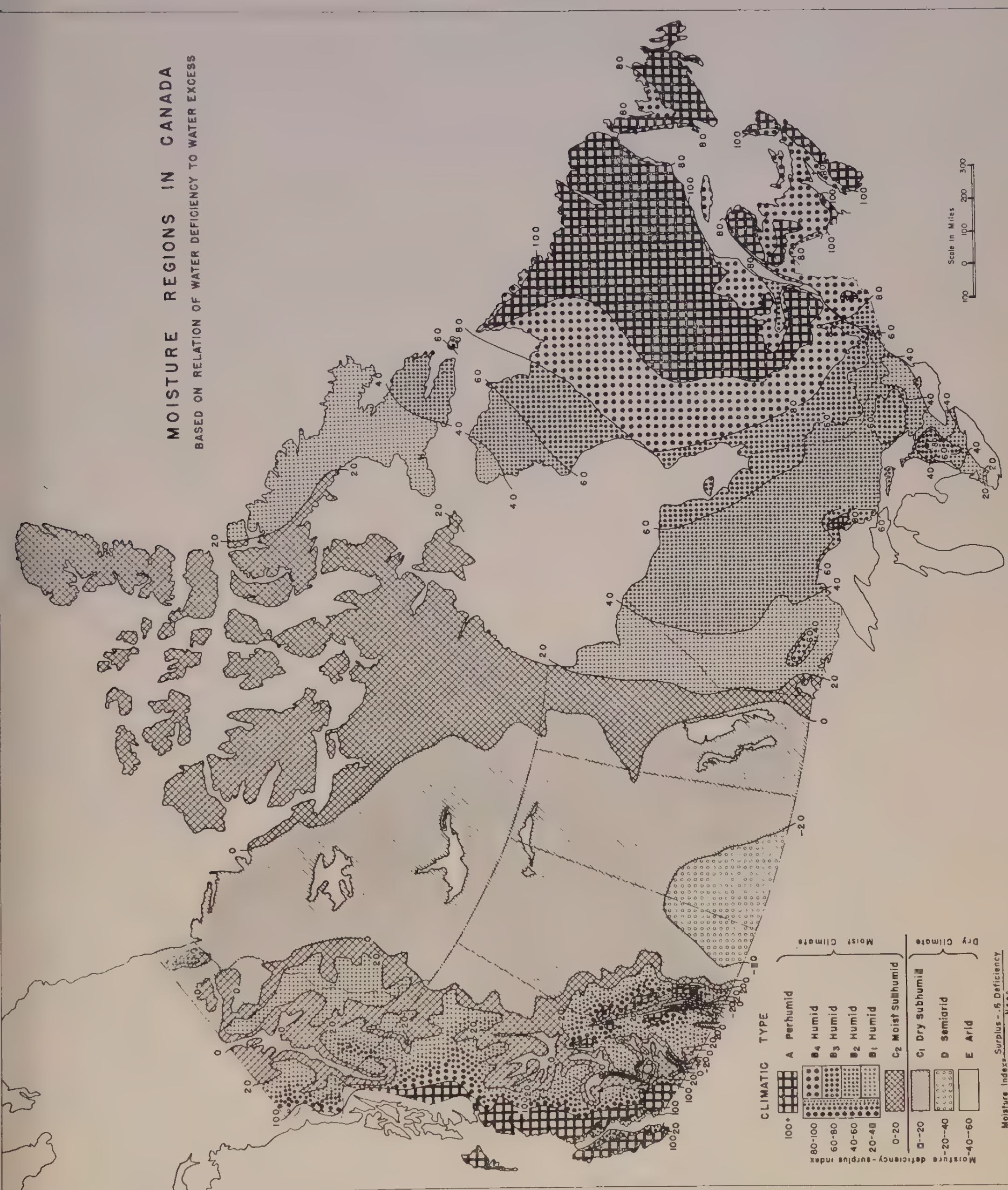


FIGURE 6

Note: B climates not differentiated in Rockies

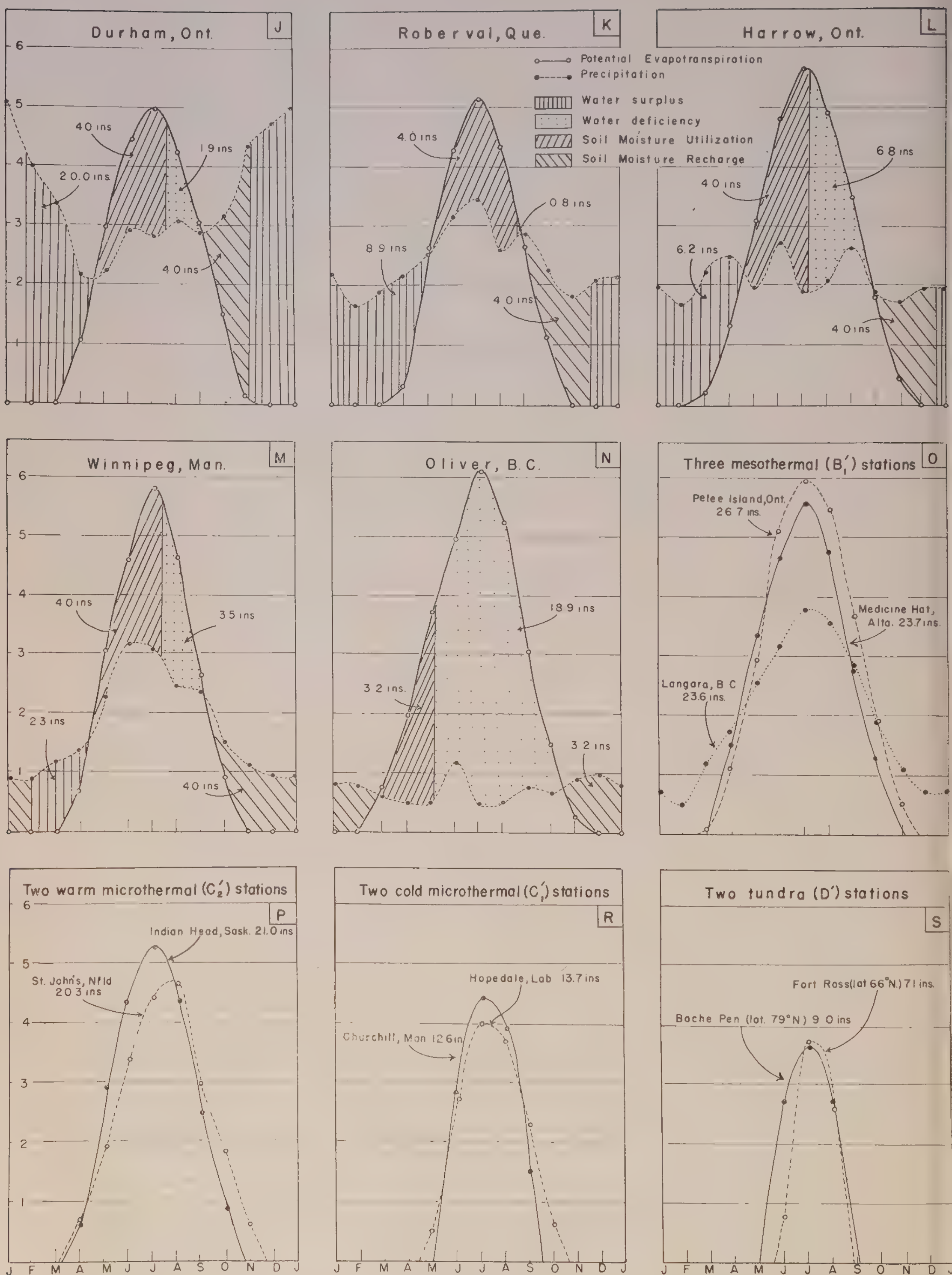

Durham, Ont.
J
20.0 ins
4 0 ins
1 9 ins
4 0 ins
Roberval, Que.
K
4.0 ins
8 9 ins
0 8 ins
4 0 ins
Harrow, Ont.
L
Potential Evapotranspiration
Precipitation
Water surplus
Water deficiency
Soil Moisture Utilization
Soil Moisture Recharge
6 8 ins
4 0 ins
6.2 ins
4 0 ins
Winnipeg, Man.
M
4 0 ins
3 5 ins
2 3 ins
4 0 ins
Oliver, B.C.
N
18 9 ins
3 2 ins.
3 2 ins
Three mesothermal (B'1) stations
O
Pelee Island, Ont. 26 7 ins.
Medicine Hat, Alta. 23.7 ins.
Langara, B C 23.6 ins.
Two warm microthermal (C'2) stations
P
Indian Head, Sask. 21.0 ins
St. John's, Nfld 20 3 ins
Two cold microthermal (C'1) stations
R
Hopedale, Lab 13.7 ins
Churchill, Man 12 6 in
Two tundra (D') stations
S
Fort Ross (lat 66°N.) 7 1 ins.
Bache Pen (lat. 79°N) 9 0 ins
J F M A M J J A S O N D J

FIGURE 7

If in any region, the two types do not coincide, the displacement of the zones is a measure of marine influence. The amount of marine influence in Canada can be seen by comparing Figure 9 with Figure 2. For example, the west coast of Vancouver Island belongs to the mesothermal B'_1 type of thermal efficiency but the summer concentration is that of megathermal a′ climate, a displacement of four zones. Marine influence is greater here than on the Atlantic coast where the displacement is only from microthermal C'_2 type to mesothermal b'_2. There is little marine influence evident along the Arctic coastal regions, except in northern Quebec where part of the D′ climate has a displacement of one zone, giving it a c'_1 summer concentration type.

SYMBOLS OF CLASSIFICATION

The climatic factors described above form the essential of the new Thornthwaite classification. They include a heat factor, a moisture factor and the seasonal variation of the two. Table 4 gives the elements of the classification and the climatic type for selected stations in Canada. A map showing the climatic types has not been prepared. For an explanation of the symbols, consider Estevan Point, the first station in Table 4. The first symbol "A" is the moisture factor, based on the relationship $\frac{\text{surplus} - \cdot 6 \text{ deficiency}}{\text{need}}$. The second symbol "$B_1$" is the heat factor, based on water need. The symbol "r" means little or no water deficiency in any season and "a′ " refers to the megathermal type of summer concentration of thermal efficiency.

TABLE 4

Station	Water need (in.)	Summer concentration, per cent	Precipitation (in.)	Water surplus (in.)	Water deficit (in.)	Surplus per cent of need	Deficit per cent of need	Moisture index	Climatic type
1. Estevan Point, B.C.	24·1	43·1	104·6	80·5	0	334·3	0	334·3	$AB'_1\ ra'$
2. Glacier, B.C.	18·6	64·8	56·2	38·2	0·6	204·9	3·2	203·0	$AC'_2\ rb'_1$
3. Chibougamau, Que.	18·8	72·5	40·3	21·5	0	114·3	0	114·3	$AC'_2\ rc'_2$
4. Resolution Is., N.W.T.	9·9	80·5	15·8	5·9	0	59·4	0	59·4	$B_2D'\ rc'_1$
5. Nanaimo, B.C.	25·6	50·4	37·6	20·1	8·1	78·3	31·5	59·4	$B_2B'_1\ sb'_4$
6. Churchill, Man.	12·6	88·3	16·1	3·9	0·4	30·6	3·4	28·6	$B_1C'_1\ rd'$
7. Leamington, Ont.	25·7	61·2	28·8	8·9	5·8	34·4	22·5	20·9	$B_1B'_1\ sb'_2$
8. Digby, N.S.	21·7	58·1	40·1	18·4	0	84·6	0	84·6	$B_4C_2'\ rb'_2$
9. Winnipeg, Man.	22·4	67·2	21·1	2·3	3·5	10·2	15·7	0·8	$C_2C_2'\ rb'_1$
10. Coppermine, N.W.T.	11·5	87·4	10·9	1·6	2·1	14·1	18·6	3·0	$C_2C_1'\ sc'_1$
11. Harrow, Ont.	25·7	59·7	25·1	6·2	6·8	24·2	26·4	8·4	$C_2B'_1\ sb'_2$
12. Lethbridge, Alta.	23·1	60·9	15·5	0·2	7·8	1·0	33·9	−19·3	$C_1B'_1\ db'_2$
13. Aklavik, N.W.T.	14·3	89·6	10·3	2·0	6·0	14·0	41·9	−11·1	$C_1C'_1\ sd'$
14. Carcross, Y.T.	16·4	71·5	8·7	0·6	8·3	3·8	51·0	−26·8	$DC'_1\ dc'_2$
15. Willow Creek, Sask.	22·2	64·5	11·1	0	11·1	0	50·2	−30·1	$DC'_2\ db'_1$
16. Peace River Crossing, Alta.	21·1	63·9	12·9	0	8·2	0	38·9	−23·3	$DC'_2\ db'_1$
17. Oliver, B.C.	27·5	59·2	8·6	0	18·9	0	68·7	−41·2	$EB'_1\ db'_2$

COMPARISON WITH FORMER CLASSIFICATION

Since many Canadian scientists are familiar with the former Thornthwaite climatic classification, the points of difference between old and new are of interest. The major dissimilarity is that the boundaries in the old classification were based on a study of soils, vegetation and drainage patterns, while the boundaries of the new classification are derived from break-points in the climatic data themselves.

The moisture symbols A, B, C, D, E in the new classification have the same meaning as the earlier moisture types, but their boundaries are different since they are differently defined. Formerly the moisture isopleths had a northern limit of T-E 32 while now the relationship between water deficiency and water surplus is taken into account everywhere. Perhumid "A" climates in the new classification now cover a much greater area in eastern Canada and the humid climates have 4 subdivisions, providing a more detailed analysis of the moisture regions. The moist subhumid tip of southern Ontario is indicated for the first time on the new map. Subhumid and semi-arid climates in the southern Prairies are similar in the two classifications but are cut off in the old classification at the thermal boundary of T-E 32. The new map indicates that, contrary to popular belief, subhumid climates are found throughout Central Canada and extend to the Arctic Ocean. The cold northern latitudes are divided for the first time into moist and dry regions. Such information should prove useful to glaciologists in explaining the origin of the continental ice sheets during the Pleistocene, since a glacier can develop only in a moist climate. Fundamental differences exist between the old and new indices of thermal efficiency. The former T-E index was based empirically on temperature; the new index is derived from temperature and length of day but is expressed as depth of water required for plant growth. The old F′ frost climate is now E′, tundra is D′, and the former D′ climate, in reality a vegetation region, is omitted. C′ denotes microthermal climates as before, but they cover a much broader area in Canada than formerly, and the B′ mesothermal climates, appear for the first time in the southern part of the Dominion.

With regard to the seasonal distribution of precipitation effectiveness, the "r" type no longer means moisture abundant in all seasons, but recognizes that even in moist climates there may be small water deficiencies. Type "d" in dry climates, formerly defined as moisture deficient in all seasons, now indicates that small water surpluses may occur. No type "s" appeared in Canada in the former classification, but in the present map, "s" is found in Southern Ontario, in the Northwest Territories and in British Columbia. A new type "s_2" is added, to emphasize those areas in humid regions with large summer water deficiencies and in arid regions those with large winter water surpluses.

SUMMARY AND CONCLUSION

The relationship of water surplus and water deficiency to water need, defined by the Thornthwaite classification, provides a new attack on the complex problems of climate in scientific agriculture as well as physical geography.

The scientific regional geographer for years has sought a rational quantitative delimitation of the climatic regions, since on it is based the

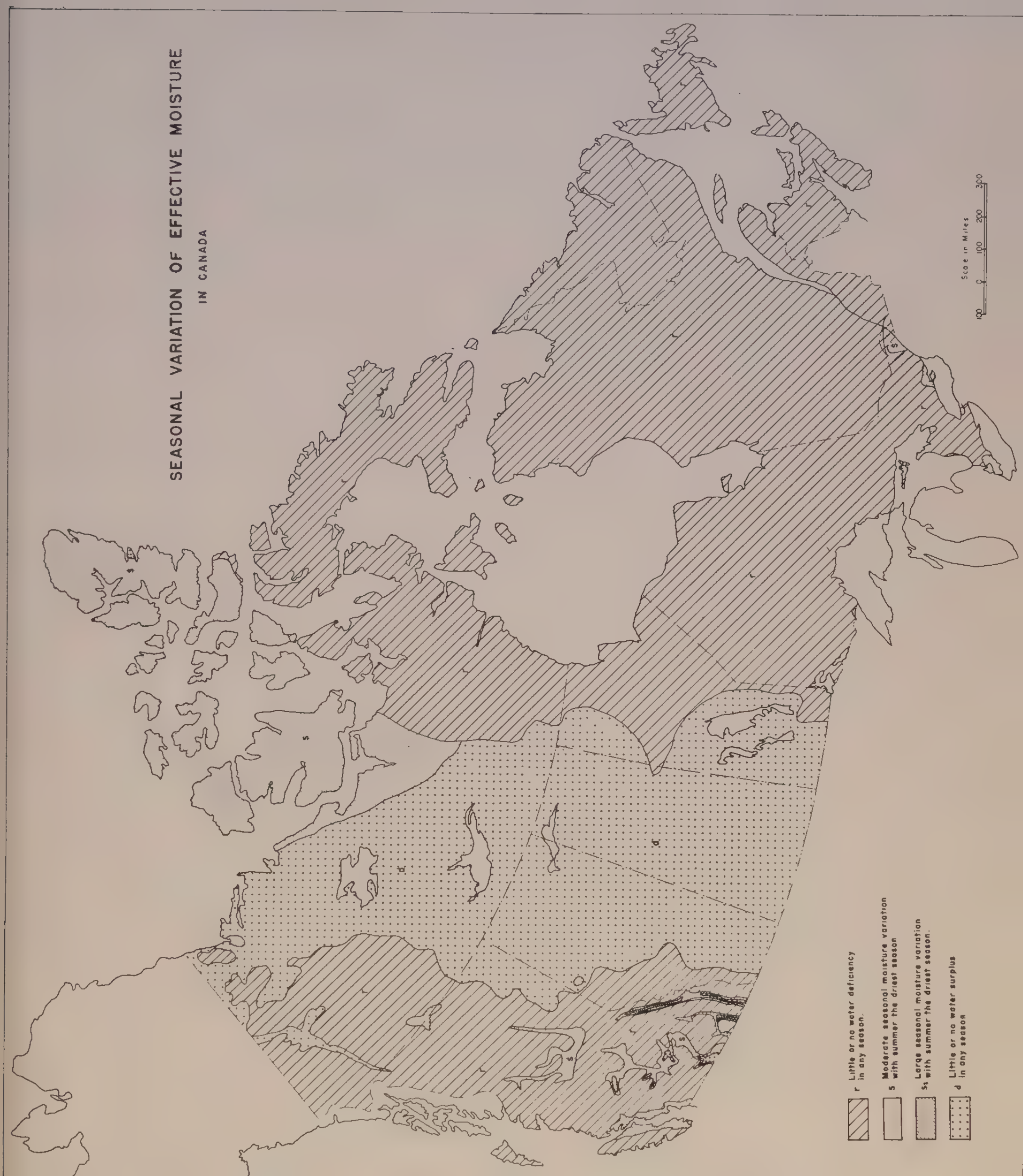

SEASONAL VARIATION OF EFFECTIVE MOISTURE
IN CANADA
r Little or no water deficiency in any season.
s Moderate seasonal moisture variation with summer the driest season
s₁ Large seasonal moisture variation with summer the driest season.
d Little or no water surplus in any season
Scale in Miles
100 0 100 200 300

FIGURE 8

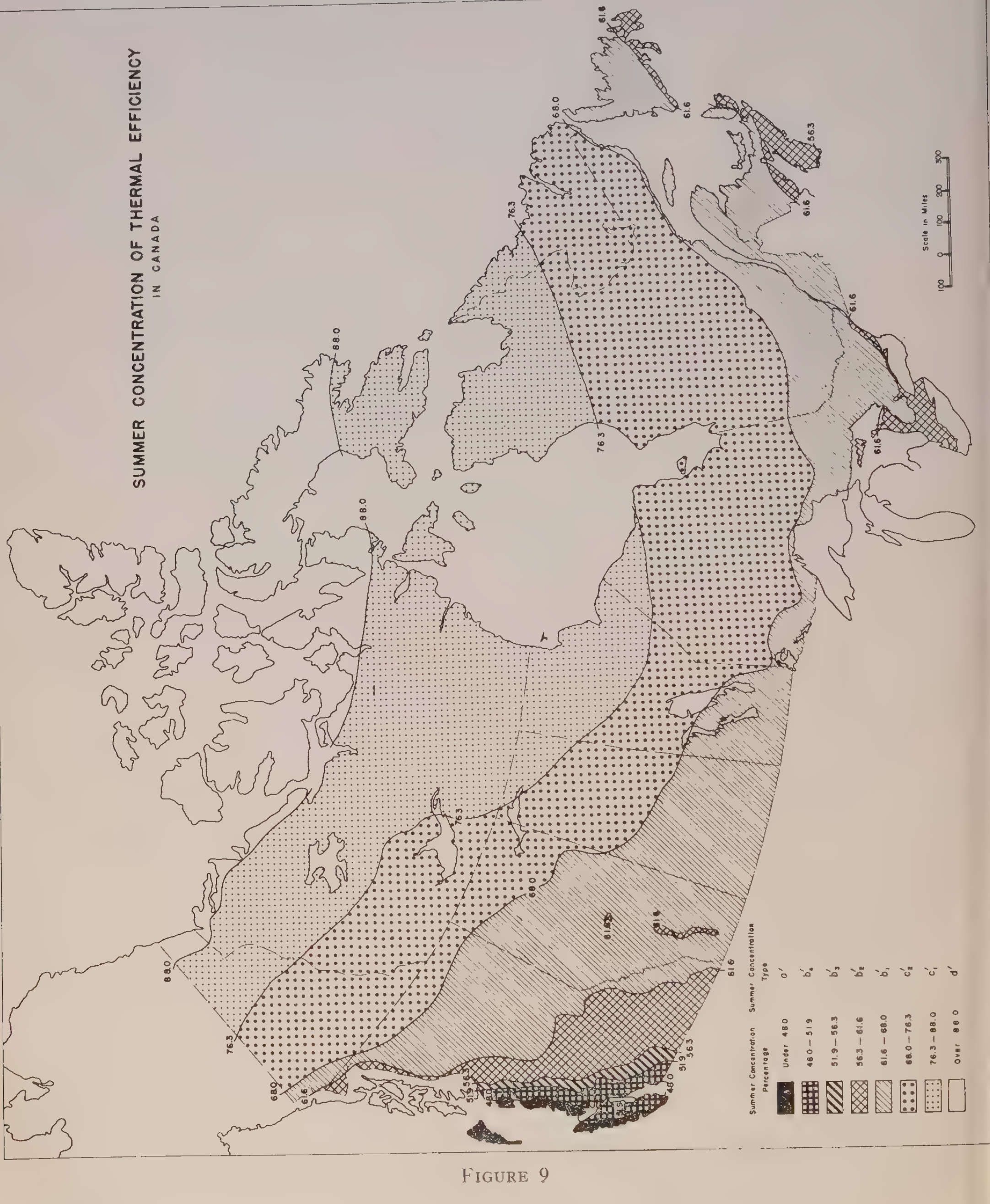

SUMMER CONCENTRATION OF THERMAL EFFICIENCY
IN CANADA
Summer Concentration Percentage
Summer Concentration Type
Under 48.0 a'
48.0 – 51.9 b'4
51.9 – 56.3 b'3
56.3 – 61.6 b'2
61.6 – 68.0 b'1
68.0 – 76.3 c'2
76.3 – 88.0 c'1
Over 88.0 d'
Scale in Miles
100 0 100 200 300

FIGURE 9

explanation of vegetation and soil zones, the geomorphic nature of the landscape and the patterns of land use. Although Koeppen's classification has served as a standard for geographers, it cannot explain the distributions of these phenomena because it is derived from them.

The hydrologist can make use of the map of water surplus for Canada in gaining an approximate knowledge of average run-off where no actual measurement is made. In addition the method of computing current water surplus for a given season from the meteorological data alone is a useful starting point in predicting available run-off.

Crop testers and plant breeders have always been hindered in their work by the lack of fundamental climatic data and quantitatively defined climatic regions. The maps of potential water need, and water deficiency presented here for Canada partially fill this gap. The map of climatic regions indicates homoclimes for the benefit of the crop tester. For example, there is an interesting similarity of moisture relations between Harrow in southwestern Ontario, and Winnipeg in Manitoba. In a crop testing program worthwhile correlations could be made between the yield and quality of the crop and actual evapotranspiration and water deficiency computed from current meteorological data.

The plant pathologist could gain a clearer knowledge of the climate advantageous to insect pests and disease organisms through a correlation of the times of infestation and the life cycle of the pathogen with related water surplus and deficiency.

Soil scientists recognize the fact that water surplus and water deficiency both play important roles in the development of soil. Thornthwaite's 0 line indicates the theoretical boundary between the pedalfer and pedocal soils. Actual soil relationships along this line remain to be investigated.

The Thornthwaite method of using meteorological statistics to arrive at a knowledge of the real factors in climate, although not perfected, represents an invaluable addition to Canadian climatic research.

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ÉTUDES SUR LA POURRITURE DU CERNE DES POMMES DE TERRE CAUSÉS PAR *CORYNEBACTERIUM SEPEDONICUM* (SPIECK. & KOTT) SKAPTASON ET BURKHOLDER

II. LES MOYENS DE LUTTE

CHAMPLAIN PERRAULT[2]

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INTRODUCTION

Les notions acquises depuis dix ans, sur la dissémination de la pourriture du cerne (flétrissure bactérienne) causée par *Corynebacterium sepedonicum* (Spieck. & Kott.) Skaptason et Burkholder, nous ont permis d'établir que le seul moyen de lutte efficace contre cette maladie est d'utiliser, comme semence, des pommes de terre qui en sont exemptes. Les nombreux travaux exécutés, ici comme ailleurs, aux fins de déterminer les agents de dissémination de la maladie ont suggéré plusieurs moyens prophylactiques importants. Ceux-ci consistent surtout à éviter le contact des tubercules atteints de pourriture avec tout ce qui peut être considéré comme agent de dissémination, tels que les outils, les instruments aratoires, les contenants, les caves, les entrepôts, les véhicules, etc. Les résultats obtenus dans le Québec ont été exposés dans un article antérieur (17).

Metzger et Glick (16), après plusieurs années d'observation de cette maladie, affirment que seuls des moyens radicaux peuvent enrayer la flétrissure dans les champs de pommes de terre. Cependant, il y a des circonstances ou d'autres moyens de lutte, sans être aussi efficaces que les précédents, peuvent parfois protéger les pommes de terre contre l'infection ou en diminuer la gravité. Les résultats que l'on a obtenus pendant ces dernières années, tant aux États-Unis qu'ici, seront exposés au cours de ce travail.

LA DÉSINFECTION DE LA SEMENCE

L'efficacité de divers désinfectants

De nombreux essais ont été faits aux États-Unis avec divers fongicides et germicides avant et après l'éclatement de la semence, mais aucun des ingrédients ne s'est avéré efficace (5, 6, 9, 11, 13, 20, 21). Les plus prometteurs sont le sublimé corrosif acidulé et non acidulé 1/500, le mercurnol, le lysol 4/200 et l'iode. Ces derniers deux ingrédients ont diminué sensiblement l'infection ainsi que le rendement, lorsque les éclats de pommes de terre y ont été trempés pendant quelques minutes; lorsque ces solutions ont servi à la désinfection des tubercules entiers, le rendement n'en a pas été diminué. Cependant, la désinfection avec l'iode n'a pas donné des résultats constants; dans plusieurs cas le traitement s'est montré totalement inefficace. Il en a été ainsi de l'oxyde jaune de mercure et du permanganate de potasse. Le cyanure de mercure a également donné de bons résultats sans causer de dommages aux éclats.

Afin d'établir jusqu'à quel point il est possible d'enrayer l'infection, lorsque celle-ci a été transmise au moyen du couteau, d'un tubercule malade aux tubercules que cet outil vient de trancher, on a fait l'essai de divers désinfectants le plus communément employés. Après avoir tranché des pommes de terre avec un couteau contaminé, on a trempé immédiatement

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TABLEAU 1.—EFFICACITÉ DE DIVERS INGRÉDIENTS DANS LA DÉSINFECTION DES ÉCLATS DE POMMES DE TERRE CONTAMINÉS AVEC LE COUTEAU

Traitements	Concentrations	Désinfection et plantation	Pourcentage des germes sortis de terre	Pourcentage des buttes flétries
Formol*	5-100	Immédiate	88	36
		5 heures après	88	52
Formol	10-100	Immédiate	72	12
		5 heures après	80	32
Bichlorure de mercure ($HgCl_2$)	1-500	Immédiate	96	56
		5 heures après	92	64
Bichlorure de mercure	1-1000	Immédiate	100	48
		5 heures après	96	64
Iode	1-100	Immédiate	100	72
		5 heures après	100	72
Mercurnol	1-100	Immédiate	92	4
		5 heures après	96	12
Lysol	5-100	Immédiate	8	0
		5 heures après	12	0
Témoin (aucun traitement)		Immédiate	100	84
		5 heures après	100	88

* Aldehyde formique 4 p. 100, couramment désigné dans le commerce sous le nom de formaline.

les morceaux dans les solutions désinfectantes durant quelques minutes, la durée du traitement variant selon l'ingrédient utilisé et sa concentration. D'autres éclats* de pommes de terre ont été trempés cinq heures plus tard permettant ainsi à l'agent pathogène de pénétrer plus avant dans les tissus. Si l'on réfère au tableau 1, on constate que seuls les trempages immédiats dans le mercurnol durant dix minutes et dans le formol, à 10 p. 100 durant cinq minutes se sont montrés efficaces, sans toutefois éliminer complètement la maladie. Le mercurnol est une solution de bichlorure de mercure et d'acide chlorhydrique préparée selon la formule suivante: six onces de sublimé corrosif dans une pinte d'acide commercial le tout dilué dans 25 gallons d'eau. Une solution de lysol à 5 p. 100 s'est également montrée efficace contre la flétrissure, mais au détriment des germes** de pommes de terre. En effet, cet ingrédient a détruit la presque totalité des germes et l'on ne peut préconiser son emploi à moins d'en diminuer la concentration.

Les composés Merphenyl: borate, chlorure, acétate, nitrate et benzoate ont été essayés en comparaison avec l'oxyde jaune de mercure et le bichlorure de mercure préparés selon les formules données antérieurement. Ces composés Merphenyl produits par Hamilton Laboratories sont des désinfectants efficaces utilisés en médecine. On les a utilisés en solutions préparées à raison d'une partie dans dix mille parties d'eau. Les tubercules

* Dans ce travail, "éclater" un tubercule signifie le couper en deux ou plusieurs morceaux avant de le mettre en terre. Les "éclats", terme que nous employons couramment, sont les morceaux obtenus en coupant les tubercules.

** On a utilisé le mot "germe" pour désigner ce que le practicien appelle l'œil du tubercule.

que l'on a inoculés en tranchant avec un couteau contaminé ont été trempés, immédiatement, cinq ou dix minutes dans chacun de ces désinfectants et plantés dans des pots de 6″ de diamètre. Les témoins ont été inoculés avec un couteau contaminé, et plantés sans aucun traitement, dans des pots de même dimension. Le diagnostic de la maladie a été basé sur la manifestation des symptômes extérieurs aussi bien que sur l'examen microscopique des empreintes prises à la base de chaque tige. Cet examen a été fait quatre-vingt-deux jours après l'inoculation.

Les résultats ont démontré qu'aucun des désinfectants n'a été satisfaisant. Les composés Merphenyl se sont montrés inférieurs au bichlorure de mercure et à l'oxyde jaune de mercure. A la suite de ces échecs répétés de deux années, on pouvait affirmer qu'avec les méthodes actuelles, la désinfection des éclats de pommes de terre est inefficace dans la lutte contre la pourriture du cerne (1).

La désinfection immédiate comparée à la désinfection différée

Dans le Kansas, on a observé que la désinfection des éclats, immédiatement après l'éclatement, a diminué sensiblement l'infection, comparativement à la désinfection différée de douze heures.

Dans une expérience, faite en 1940, à Sainte-Anne-de-la-Pocatière, on a voulu connaître l'effet de la désinfection différée sur la maladie. A cette fin, l'oxyde jaune de mercure a été utilisé comme désinfectant à raison d'une livre dans douze gallons d'eau. Une faible partie de cet ingrédient se dissout dans l'eau, tandis que le reste demeure en suspension. Les éclats de pommes de terre y sont trempés pendant dix minutes et ensuite étendus sur le plancher pour sécher.

Les pommes de terre ont été coupées avec un couteau contaminé et les morceaux répartis en six lots de deux cents éclats chacun. Deux de ces lots ont été plantés immédiatement, l'un sans désinfection préalable, l'autre après désinfection. Deux autres lots ont été plantés cinq heures plus tard, l'un sans désinfection, l'autre après avoir trempé les éclats dans le désinfectant, quelques minutes avant la plantation. Les derniers deux lots ont été plantés une journée après avoir tranché les tubercules, l'un sans désinfection, l'autre après avoir désinfecté les tubercules tranchés et infectés la veille. Chacun de ces traitements comprenait 200 tubercules. Les résultats exposés dans le tableau 2 démontrent que l'oxyde jaune de mercure diminue l'infection, mais que le traitement n'est pas suffisamment efficace. La désinfection retardée d'une journée est inutile et l'on considère que c'est du temps et de l'argent perdus.

Tableau 2.—Effet de la plantation différée plus ou moins longtemps après l'éclatement des tubercules contaminés avec le couteau

Plantation	Pourcentage des plants sortis de terre		Pourcentage des buttes flétries	
	Sans désinfection	Après désinfection	Sans désinfection	Après désinfection
Immédiate	95.0	98.0	90.5	51.02
Cinq heures plus tard	93.5	91.5	92.5	62.84
Une journée plus tard	100.0	96.0	95.0	86.45

LA DÉSINFECTION DU COUTEAU

Certains cultivateurs progressifs trempent leurs couteaux dans des solutions désinfectantes après avoir éclaté chaque tubercule ou encore après avoir éclaté un tubercule douteux, afin de ne pas infecter le reste de leur semence. Nous avons cru qu'il était nécessaire de connaître la valeur des solutions communément employées, afin de pouvoir faire les recommandations appropriées.

Aux États-Unis, des investigateurs (5, 22) ont trouvé les traitements suivants très efficaces: les trempages dans *a*) l'eau bouillante durant quinze secondes; *b*) le sublimé corrosif acidulé et non acidulé, 1 partie dans 1000, durant cinq minutes et plus; *c*) des solutions de formol, 1 partie dans 15, durant dix minutes ou 1 partie dans 30, durant quinze minutes; *d*) la teinture d'iode à 1 p. 100; *e*) le lysol à 5 p. 100 et *f*) l'alcool ethylique à 70 p. 100. Les producteurs qui utilisent le couteau rotatif pour couper les tubercules de semence peuvent désinfecter celui-ci en le faisant tremper dans de l'eau chaude ou bouillante ou dans une solution de bichlorure de mercure (11, 13, 14, 15).

En 1940, on a éclaté un certain nombre de tubercules sains en trois morceaux. Un premier morceau a été tranché avec un couteau stérilisé et planté pour servir de témoin aux deux autres morceaux. Ceux-ci ont été coupés avec un couteau contaminé que l'on a trempé au préalable dans l'une des solutions à l'essai. La durée des traitements a varié de une à cinq minutes. Trois mois après la plantation, des empreintes ont été prises de chacune des tiges et des tubercules qui y étaient attachés. Les diagnostics basés sur l'examen microscopique des empreintes sont exposés dans le tableau 3. Les résultats de cette expérience indiquent que, des divers traitements mis à l'épreuve, seuls l'alcool à 20 p. 100 et les trempages, durant une et deux minutes dans le formol à 5 p. 100, ont été sans valeur

TABLEAU 3.—EFFICACITÉ DE DIVERS DÉSINFECTANTS DANS LA STÉRILISATION DU COUTEAU QUI SERT A ÉCLATER LES TUBERCULES

Traitements	Concentrations	Durée des traitements	État sanitaire des plants	
			Témoins	Inoculés
Formol	10-100	1, 2, 3, 4 et 5 min.	Sain	Sain
Formol	5-100	1 et 2 min.	Sain	Flétrissure
Formol	5-100	3, 4 et 5 min.	Sain	Sain
Alcool	20-100	1, 2, 3, 4 et 5 min.	Sain	Flétrissure
Alcool	50-100	1, 2, 3, 4 et 5 min.	Sain	Sain
Alcool	70-100	1, 2, 3, 4 et 5 min.	Sain	Sain
Alcool	80-100	1, 2, 3, 4 et 5 min.	Sain	Sain
Alcool	90-100	1, 2, 3, 4 et 5 min.	Sain	Sain
Alcool*	70-100	——	Sain	Sain
Alcool*	80-100	——	Sain	Sain
Alcool*	90-100	——	Sain	Sain
Hypochlorite de calcium	5-100	1, 2, 3, 4 et 5 min.	Sain	Sain
Hypochlorite de calcium	10-100	1, 2, 3, 4 et 5 min.	Sain	Sain
Bichlorure et cyanure de mercure	1/16 oz. 1 pinte d'eau	1 et 2 min.	Sain	Sain

* Le couteau est flambé après avoir été trempé dans l'alcool.

contre l'agent pathogène de la flétrissure. Les plants provenant des tubercules qui ont été tranchés avec un couteau contaminé et trempé dans ces deux solutions ont manifesté les symptômes de flétrissure.

L'examen d'empreintes de tubercules et de tiges prises selon la méthode déjà décrite par Savile et Racicot (18), dans le but de découvrir la présence de bactéries, nous a suggéré l'expérience suivante aux fins de déterminer le moyen le plus efficace de stériliser le scalpel. Lorsque l'on a plusieurs empreintes à prendre, il est important qu'il n'y ait pas de bactéries collées au scalpel, car celles-ci adhèrent à la surface tranchée du tubercule ou de la tige et sont transmises à la lame avec l'empreinte. La présence de ces bactéries sur des empreintes de tiges saines peuvent induire l'examinateur en erreur quant à l'état sanitaire des sujets examinés. Divers modes de stérilisation du scalpel ont été essayés, après avoir tranché une tige ou un tubercule gravement atteint de pourriture du cerne.

Dans une première série d'essais le scalpel a été contaminé en le passant dans une tige atteinte de flétrissure, avant de le soumettre au traitement. Après le traitement on a tranché un pétiole de pomme de terre saine et pris une empreinte de la surface coupée, afin de voir si des bactéries y avaient été déposées. Chaque opération a été reprise neuf fois pour chacun des traitements. Dans une deuxième et une troisième séries d'essais le scalpel a été contaminé en tranchant dans un tubercule atteint de pourriture. Mais dans la dernière série, les pétioles de pommes de terre qui étaient utilisés pour faire les empreintes dans les première et deuxième séries ont été remplacés par des cylindres prélevés de tubercules sains. On a exprimé la densité des bactéries sur chacune des empreintes par des symboles numériques variant de 0 à 5. Les données exposées dans le tableau 4 représentent la moyenne de la somme des valeurs des trois répétitions ou séries d'essais mentionnées plus haut et comprenant dix empreintes chacune. Leur analyse statistique démontre qu'une différence moyenne significative de 13.4 est requise dans l'appréciation des résultats. Ceux-ci révèlent donc que les meilleures façons de nettoyer le scalpel des bactéries qui adhèrent sont: 1° de le chauffer pendant quelques minutes à la flamme du bec Bunsen; 2° de le laver à l'eau courante en le frottant avec les doigts ou un tampon de coton hydrophile. On constate également qu'il est plus difficile de nettoyer le scalpel lorsqu'on lui a donné le temps de sécher après s'en être servi. Le scalpel est plus facilement nettoyé si l'on essuie la lame avec un tampon de coton ou une serviette immédiatement après avoir tranché le sujet malade. Le lavage du scalpel dans le formol à 5 p. 100, même en frottant, n'est pas aussi efficace qu'un lavage à l'eau courante.

EFFET DES RAYONS SOLAIRES SUR L'INFECTION

Trois cents éclats de pommes de terre, inoculés avec le couteau, ont été exposés trois à quatre heures au soleil ardent des premiers jours de juin et plantés en pleine terre. Dans une autre parcelle, le même nombre d'éclats inoculés de la même façon ont été plantés aussitôt après inoculation. Ce travail exécuté à Sainte-Anne-de-la-Pocatière et à Mont-Joli, en 1938, a été répété en 1939, à Sainte-Anne seulement. Cette fois, l'exposition au soleil a été prolongée de quatre heures. Les résultats que l'on a rassemblés dans le tableau 5 démontrent que la plantation différée, permettant l'action

TABLEAU 4.—DENSITÉ DES BACTÉRIES LAISSÉES SUR LES EMPREINTES DE PÉTIOLES ET DE TUBERCULES PAR LE SCALPEL CONTAMINÉ ET DÉSINFECTÉ SELON LES TRAITEMENTS SUIVANTS

Traitements	Moyenne de trois répétitions de dix empreintes chacune
1. Scalpel contaminé, section, sans désinfection	30.0 ± 5.4
2. Scalpel contaminé, lavé à l'eau courante sans frotter, section	13.6
3. Scalpel contaminé, lavé à l'eau courante en frottant, section	6.3
4. Scalpel contaminé, séché, lavé à l'eau courante, section	24.6
5. Scalpel contaminé, séché, lavé à l'eau courante en frottant, section	6.0
6. Scalpel contaminé, séché, lavé à l'eau courante en frottant, alcool, flamme, section	3.5
7. Scalpel contaminé, essuyé, section	18.6
8. Scalpel contaminé, séché, section	33.5
9. Scalpel contaminé, séché, essuyé, section	29.6
10. Scalpel contaminé, alcool, flamme, section	31.6
11. Scalpel contaminé, essuyé, alcool, flamme, section	11.3
12. Scalpel contaminé, séché, alcool, flamme, section	31.6
13. Scalpel contaminé, séché, essuyé, alcool, flamme, section	17.0
14. Scalpel contaminé, alcool 2 minutes, flamme, section	28.3
15. Scalpel contaminé, alcool 5 minutes, flamme, section	27.0
16. Scalpel contaminé, séché, alcool 5 minutes, flamme, section	27.0
17. Scalpel contaminé, séché au-dessus flamme, alcool, flamme, section	25.6
18. Scalpel contaminé, alcool, chauffé-rouge, refroidi, section	0.0
19. Scalpel contaminé, chauffé-rouge, refroidi, section	0.0
20. Scalpel contaminé, dans le formol 5 p. 100 1 minute, section	23.0
21. Scalpel contaminé, dans le formol 5 p. 100 lavé en frottant, section	8.5
22. Scalpel contaminé, dans le formol 5 p. 100, lavé en frottant, alcool, flamme, section	9 5

Moyenne significative à 0·05 = 13·4).

du soleil et du vent sur les éclats, a eu pour effet de diminuer l'infection de 8 p. 100 à Mont-Joli et de 10 à 25 p. 100 à Sainte-Anne-de-la-Pocatière. C'est un moyen de lutte qui peut être mis à l'essai sur certaines fermes pendant les journées chaudes et ensoleillées du printemps, lorsque les cultivateurs se voient dans l'impossibilité de renouveler leur semence après y avoir constaté la présence de la maladie. Cependant, il est bon de faire remarquer que les pommes de terre ainsi coupées doivent être étendues en couche mince sur le sol, autrement, les tubercules des couches inférieures ne subiront pas l'action des rayons solaires.

TABLEAU 5.—EFFET DE LA LUMIÈRE SOLAIRE ET DE LA PLANTATION DIFFÉRÉE SUR LA FLÉTRISSURE BACTÉRIENNE

Localités	Pourcentage des buttes flétries dans la plantation		Pourcentage des tubercules pourris dans la plantation	
	Immédiate	Différée	Immédiate	Différée
1938				
Mont-Joli	94.3	86.3	84.8	74.0
Sainte-Anne	88.0	63.0	66.9	54.0
1939				
Sainte-Anne	96.0	86.3	77.1	56.8
Moyenne	92.8	78.5	76.3	61.6

Starr a confirmé l'effet sanitaire du soleil en démontrant que des sacs contaminés avec *C. sepedonicum* et exposés aux rayons solaires durant une quarantaine de jours ont perdu, de façon appréciable, le pouvoir de transmettre la maladie (23).

L'ÉPURATION D'UNE SEMENCE CONTAMINÉE

Plusieurs cultivateurs, chez qui la flétrissure cause plus ou moins de dommages, se contentent d'arracher les plants malades dans leur champ de pommes de terre, croyant ainsi réussir l'épuration de leur récolte. Nous ne voulons pas décourager ceux qui se livrent à cette pratique, mais il est certain que s'ils désirent réussir, ils devront procéder systématiquement et y mettre beaucoup de temps et de patience.

Au printemps de 1938, on a planté par unités un certain nombre de tubercules apparemment sains, provenant de la récolte gravement infectée d'un producteur de Mont-Joli. A l'automne, à la suite d'un examen minutieux de chaque tubercule, on a trouvé trente-huit unités apparemment saines sur les soixante-dix-huit unités que l'on avait mises en terre. La récolte des unités dans lesquelles il y avait de la flétrissure a été répartie en deux lots comprenant l'un, les buttes saines des unités atteintes de flétrissure, l'autre, les tubercules apparemment sains des buttes atteintes de cette maladie. Les tubercules qui montraient les symptômes de pourriture ont été rejetés, tandis que les autres ont été conservés en cave jusqu'au printemps suivant. Les tubercules provenant des unités entièrement saines ont été plantés avec la planteuse mécanique après avoir désinfecté celle-ci au formol, tandis que les tubercules provenant des deux lots mentionnés plus haut ont été plantés selon la méthode du tubercule isolé.

Lors de la récolte, à l'automne de 1939, 2 p. 100 des buttes plantées avec la planteuse mécanique étaient atteintes de flétrissure et cependant, la semence provenait d'unités entièrement saines, du moins en apparence. Des cent dix-neuf unités dont la semence provenait de buttes apparemment saines, mais d'unités malades, quarante-sept étaient atteintes de flétrissure. Le travail de sélection, c'est-à-dire la répartition de la récolte en trois catégories, comme en 1939, a été continuée en 1940, lors de la récolte. Le printemps suivant tous ces tubercules ont été plantés selon la méthode du tubercule isolé et ce n'est que dans la catégorie de semence provenant d'unités entièrement saines que l'on a réussi à produire une récolte exempte de flétrissure. Les résultats rassemblés dans le tableau 6 démontrent bien qu'il est possible d'épurer une récolte infectée de pourriture du cerne, 1° en plantant les pommes de terre par unités isolées, 2° en ne choisissant comme semence que le produit des unités entièrement saines.

Il est évident que le procédé est long et nullement pratique. Nous ne le conseillons qu'aux producteurs avertis et désireux de conserver certaines lignées de pommes de terre.

Un travail similaire a été effectué aux États-Unis en 1940 (7, 16) avec cette différence que les tiges et les tubercules sur lesquels on ne voyait aucun symptôme extérieur, ont été examinés au microscope. Ceci représente un travail considérable lors de la récole, mais cet examen, si

TABLEAU 6.—POURCENTAGE D'UNITÉS ET DE BUTTES SAINES OBTENUES PENDANT TROIS ANNÉES CONSÉCUTIVES DANS UN ESSAI D'ÉPURATION D'UNE SEMENCE GRAVEMENT ATTEINTE DE POURRITURE DU CERNE

Provenance de la semence	Nombre d'unités mises en terre	Pourcentage d'unités saines	Pourcentage de buttes saines
1939			
B—Buttes apparemment saines d'unités malades	119	70	89
C—Tubercules apparemment sains de buttes malades	72	34	64
1940			
A—Buttes des unités entièrement saines	200	98	99
B—Buttes apparemment saines d'unités malades	200	61	81
C—Tubercules apparemment sains de buttes malades	200	26	52
1941			
A—Buttes des unités entièrement saines	300	100	100

long soit-il, facilite l'épuration d'un champ ou d'une parcelle de pommes de terre. D'autres (5, 20, 25), par contre, ne favorisent pas la sélection des tubercules sains dans une récolte infectée de pourriture du cerne car, prétendent-ils, elle ne donne pas de résultats satisfaisants.

En certains milieux (8, 10), on a préconisé l'emploi de la lumière ultra-violette pour diagnostiquer la maladie dans les tubercules, affirmant que la méthode est aussi satisfaisante et plus rapide que la prise d'empreintes. Cependant, des travaux ultérieurs (3, 11, 19) ont démontré qu'il n'était pas sage de s'en tenir uniquement à cette méthode pour éliminer la maladie dans une récolte.

SUSCEPTIBILITÉ DES VARIÉTÉS DE POMMES DE TERRE

Toutes les variétés de pommes de terre que l'on a essayées sont sujettes à la pourriture du cerne comme le démontrent les inoculations faites en 1938 et 1939, inoculations dont on a déjà souligné les résultats ailleurs (4).

Pendant l'année 1938, dix-huit variétés ont été inoculées, afin de connaître le degré de résistance ou de susceptibilité de chacune d'elles à la maladie. Les inoculations ont été faites avec un couteau contaminé. Avant d'éclater chaque tubercule, la lame du couteau a été passée dans un tubercule gravement atteint de pourriture. Les tubercules utilisés dans cette expérience ont été prélevés de pommes de terre récoltées, l'année précédente, d'une parcelle isolée dans laquelle on n'a observé aucune trace de maladie. Les résultats de 1938 que l'on a rassemblés dans le tableau 7 révèlent que seules les variétés Rural Blush et Donard offrent une certaine résistance à la maladie. La récolte de toutes ces variétés a été conservée

Tableau 7.—Susceptibilité des variétés de pommes de terre à la pourriture du cerne à la suite d'inoculations avec un couteau contaminé

Variétés	Pourcentage des buttes atteintes de flétrissure			Pourcentage des tubercules atteints de flétrissure		
	Mont-Joli 1938	Mont-Joli 1939	Ste-Anne 1939	Mont-Joli 1938	Mont-Joli 1939	Ste-Anne 1939
1. Arran Banner	96.5	—	91.6	87.9	—	69.0
2. Arran Consul	91.6	50.0	—	70.6	26.8	—
3. Arran Chief	100.0	—	97.9	76.0	—	73.1
4. Arran Victory	—	—	84.0	—	—	49.2
5. Bally Doon	—	81.6	—	—	60.4	—
6. British Queen	—	—	86.7	—	—	64.5
7. Burbank	—	—	85.0	—	—	69.5
8. Carman N° 1	—	—	87.5	—	—	65.8
9. Carman N° 3	97.2	—	80.5	91.5	—	83.3
10. Chippewa	—	73.3	90.9	—	44.5	63.8
11. Dakota Red	—	—	58.8	—	—	17.0
12. Davies Warrior	100.0	—	85.7	86.8	—	80.9
13. Donard	54.1	40.0	91.0	65.0	22.5	54.7
14. Dooley	100.0	75.0	—	86.2	63.7	—
15. Dunbar Yeoman	85.7	81.6	80.3	92.3	52.1	65.0
16. Garnet Chili	—	41.6	—	—	52.6	—
17. Gold Nugget	—	—	75.0	—	—	87.6
18. Great Scot	85.7	85.0	77.0	84.0	59.7	48.5
19. Green Mountain (Montagne Verte)	96.8	80.0	96.6	75.6	67.9	73.7
20. Houma	91.6	88.3	95.0	77.9	56.4	71.1
21. Irish Cobbler	85.7	93.3	94.0	87.2	65.9	81.8
22. Katahdin	96.8	73.3	—	100.0	54.1	—
23. McGregor	—	—	93.7	—	—	68.5
24. McIntyre Blue	—	—	84.3	—	—	50.6
25. President	—	—	70.4	—	—	29.5
26. Prolifique	96.5	75.0	83.3	84.1	47.2	68.3
27. Rapid Transit	—	—	100.0	—	—	85.0
28. Rural Blush	46.4	—	36.7	39.8	—	22.0
29. Spaulding Rose	100.0	75.0	70.0	96.1	82.1	75.5
30. Sunrise	83.3	—	—	69.4	—	—
31. Up to Date	—	—	92.5	—	—	73.0
32. Warba	100.0	—	82.1	84.9	—	66.3

en cave et examinée au cours de l'hiver, afin de faire le partage des tubercules sains et des tubercules atteints de pourriture. Au printemps, après un dernier examen, le pourcentage de tubercules sains a été déterminé et l'on a constaté que de toutes les variétés inoculées, la Rural Blush a perdu le moins de tubercules. La variété Donard, qui avait déjà perdu la moitié de ses tubercules lors de la récolte, a réussi à en conserver 35 p. 100 au printemps.

Cette expérience a été répétée en 1939 à Sainte-Anne-de-la-Pocatière et à Mont-Joli. La méthode d'inoculation a été la même qu'en 1938 et le nombre de tubercules inoculés a été plus élevé, soit une soixantaine par variété. Les résultats de ces essais ont été condensés dans le tableau 7, où l'on peut constater leur ressemblance avec ceux de l'année précédente. La variété *Rural Blush* se montre encore plus résistante que les autres variétés, tandis que *President*, *Dakota Red* et *Donard* occupent les deuxième, troisième et quatrième places. Cependant, ces différences entre les variétés ne sont pas suffisamment prononcées et constantes pour nous permettre une appréciation sur la résistance de ces variétés. Néanmoins, il est évident qu'elles offrent des possibilités.

A la Station expérimentale du Wyoming (25), où l'on a fait l'essai de plusieurs variétés, celles dont les noms suivent ont montré beaucoup de résistance: *Russet Rural*, *Brown Beauty*, *Golden*, *Red McClure*, *Downing Rural* et *King*. Un certain nombre de semis offrent plus ou moins de résistance, tandis que le croisement U.S.D.A. 47102 se montre totalement résistant. Depuis ce temps les travaux se sont poursuivis aux États-Unis où l'on a réussi à produire quelques variétés et semis de pommes de terre dont la résistance à la pourriture du cerne est bien établie (2).

CONCLUSIONS

Il ne faudrait pas que les résultats obtenus avec les moyens de luttes que l'on vient de relater soient un motif d'encouragement à y recourir de préférence aux moyens plus efficaces. La désinfection des semences ne doit être recommandée que lorsque la maladie est bénigne. Si la maladie est grave, il est préférable de ne pas utiliser les pommes de terre comme semence. Vu la facilité avec laquelle la maladie peut être disséminée lors de la plantation ou à la récolte, on considère que 1 p. 100 de pourriture dans une semence constitue un cas grave. Il n'y a qu'un seul moyen de lutte efficace connu à date contre cette maladie; c'est d'éliminer toute récolte qui en est infectée et de ne jamais utiliser comme semence des tubercules provenant de celle-ci. Les autres moyens ne doivent être utilisés que lorsque l'on n'a pu recourir au premier.

La désinfection de la semence selon les procédés actuels n'est pas très efficace. Cependant, cette désinfection lorsqu'elle est faite conjointement avec celle du couteau et des autres instruments peut contribuer à maintenir le taux d'infection assez bas. La désinfection du couteau est plus facile que celle de la semence. La plupart des désinfectants utilisés dans la désinfection des couteaux donnent des résultats satisfaisants, tandis que l'action des mêmes ingrédients sur la semence est bien peu avantageuse.

La désinfection des instruments tels que les planteuses et arracheuses mécaniques, les cribles ainsi que les caveaux, les entrepôts et les divers contenants lorsqu'ils sont venus en contact avec des tubercules atteints de pourriture du cerne, est une pratique que l'on doit conseiller, mais encore faut-il que la désinfection soit bien faite. Les résultats que l'on a rapportés antérieurement (17) démontrent la possibilité de diminuer le taux d'infection dans un champ, en désinfectant la planteuse mécanique avec une solution concentrée de formol. Knorr, en 1947 (12), affirme qu'il a obtenu la désinfection complète des surfaces de bois et de métal avec cinq ou six désinfectants, entre autres, le sulfate de cuivre, le sublimé corrosif et le formol. Cependant, les pièces contaminées qu'il utilisa ne peuvent être comparées aux parties encrassées des instruments aratoires que l'on doit soumettre aux mêmes traitements. La désinfection de ces derniers est beaucoup plus difficile. A la Station expérimentale de Virginie (26) on recommande de désinfecter les caveaux, planchers, sacs et boîtes avec une solution de formol en mélangeant une chopine de cet ingrédient dans quinze gallons d'eau; on recommande aussi la désinfection de la machinerie avec une solution de lysol préparée à raison de deux cuillerées et demie à thé dans un gallon d'eau. Dans le Wyoming (24) on a recommandé la stérilisation des sacs en les soumettant à la vapeur sous pression.

Différer la désinfection de la semence de quelques heures après l'avoir éclatée augmente la gravité de la maladie. Cela peut paraître contradictoire avec les résultats obtenus lorsqu'on retarde de quelques heures la plantation de tubercules fraîchement coupés, afin de les exposer au soleil. Dans le premier cas, la semence éclatée est maintenue sous abri, loin des rayons solaires permettant ainsi à l'agent pathogène de pénétrer plus avant dans les tissus, tandis que dans le dernier cas son avance est entravée par le soleil et les vents desséchants.

Encore une fois, tous ces moyens ne sont que secondaires et ne doivent être utilisés que lorsqu'on n'a pu disposer d'une récolte ou d'une semence atteinte de flétrissure. Malheureusement, ce moyen radical de disposer d'une récolte n'est pas populaire chez les cultivateurs et serait bien mal venu celui qui voudrait imposer une réglementation à cette fin. Il reste encore un espoir de voir diminuer sinon disparaître cette maladie dans la province de Québec; il réside dans l'utilisation de variétés résistantes. Là encore faudra-t-il que celles-ci possèdent au moins les qualités culinaires de nos principales variétés commerciales.

RÉSUMÉ

La désinfection des pommes de terre éclatées ou non n'est pas un moyen bien efficace dans la lutte contre la pourriture du cerne. Parmi les nombreux désinfectants que l'on a essayés, les plus satisfaisants sont le formol et le mercurnol. Le lysol à 5 p. 100 est aussi un désinfectant efficace, mais il faudrait l'employer en solution plus faible, afin de ne pas endommager la semence et alors il perdrait probablement son efficacité.

Différer la désinfection des éclats de quelques heures seulement contribue à augmenter la gravité de la maladie dans un champ.

Parmi les différentes concentrations d'alcool et de formol utilisées, seuls les trempages dans l'alcool à 20 p. 100 et dans le formol à 5 p. 100, durant une et deux minutes, n'ont pas désinfecté le couteau de façon satisfaisante. Mais lorsqu'il s'agit de nettoyer le couteau des bactéries qui y adhèrent, après avoir tranché un tubercule ou une tige malade, il faut soit chauffer à rouge la lame du couteau, soit laver celle-ci à l'eau courante en la frottant avec les doigts ou un tampon de ouate.

Exposer au soleil, durant quelques heures, les éclats de pommes de terre fraîchement coupées réduit quelque peu l'infection qui a pu se produire en éclatant les tubercules avec un couteau contaminé.

L'épuration d'une semence contaminée est chose possible tout en demeurant un procédé lent et peu pratique.

De toutes les variétés de pommes de terre essayées aux fins de connaître leur réaction envers *C. sepedonicum* seules *Rural Blush*, *President* et *Dakota Red* ont montré quelque degré de résistance.

ENGLISH SUMMARY

The disinfection of potato tubers, either whole or cut, is not an effective means of controlling bacterial ring rot. Among the various disinfectants tested, formalin and mercurnol were the most efficient. A five per cent solution of lysol was also effective, but caused injury to the sets.

A delay of a few hours in disinfecting potato sets cut with a contaminated knife may increase the amount of disease in the field.

Immersion of a contaminated knife in 20 per cent alcohol for from one to five minutes or in formalin for one or two minutes did not satisfactorily disinfect it. Furthermore, to remove all bacteria from the blade of the knife used to cut stems and tubers in making smears for microscopical examinations, it is necessary to heat the blade over a flame until it is red hot, or to wash it under running water with the fingers or absorbent cotton. Otherwise, either dead or living bacteria adhering to the blade may be deposited on the smears subsequently made from healthy plants.

Exposure of freshly-cut potato sets to the sun for a few hours tends to reduce the amount of infection that would have taken place if they were cut with a contaminated knife.

Roguing diseased plants in the field is a slow and impracticable method of controlling bacterial ring rot. The disease, however, may be completely eliminated from a lot of potatoes by planting by tuber-unit and roguing, provided every sanitary precaution has been taken.

Among the different varieties of potatoes tested for ring rot resistance. Rural Blush, President, and Dakota Red were the only ones that showed any promise.

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Like its four predecessors the fifth edition of *Commercial Flower Forcing* is a distinct contribution to the florist industry.

Written by the two men whose work at Ohio State University has given so much leadership in bringing methods of growing flowers abreast of the times, it pilots the commercial grower in a direct manner through the seemingly complicated channels that science and modern invention have devised to meet changing conditions.

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The chapter on heating puts much previously hard-to-find information in a concise form. That on diagnosing greenhouse ills, gives a wealth of helpful information on disease and pest control and the identification of physiological troubles in quickly available tabular form and the chapter on production costs, though one may argue with individual items, gives a yardstick by which any grower can check the financial efficiency of his methods.

It is a book that will be useful on the desk of every practical grower and scientific worker connected with the florist industry.

—R. W. Oliver

Common British Grasses and Legumes, by J. O. Thomas, M.Sc., N.D.A., N.D.D. and L. J. Davis. Longmans, Green and Company, London, New York, Toronto. 120 pages. Second Edition 1946. $2.50.

This book contains a description of the commonly grown grasses and forage legumes of Great Britain. There are keys for the identification of grasses and legumes by vegetative characters as well as botanical descriptions of 27 grasses and 16 legumes. The botanical descriptions include illustrated drawings and descriptions of floral and vegetative organs as well as the geographical distribution and economic value of each species. Most of these legumes and more than half of the grass species are grown in Canada.

—H. A. McLennan

The Fruit and the Soil. Collected Edition of the John Innes Leaflets. Edited by Cyril D. Darlington. Oliver and Boyd, Edinburgh.

This collected edition of John Innes Leaflets deals with such subjects as composts and soil sterilization for pot plants; the fertility rules in fruit planting; growing tomatoes out-of-doors, and growing pure seed.

Standardized formulae of composts for specific crops and purposes are given. While some of the ingredients may not be easily available in this country the principle of standardizing composts commends itself. Varieties of cherries, plums and apples are listed according to their chromosome numbers and the question of inter-varietal compatability is discussed from the standpoint of pollination. While this type of information is of great practical value a large number of the varieties listed are not grown in this country. The section on tomatoes would be of little benefit to Canadian growers since the methods advised are largely regulated by very different climatic conditions. The section on growing pure seed contains much useful information that could be applied under Canadian conditions. This booklet contains valuable practical information for the English grower. gardener and seedsman but a considerable portion of the information is not applicable to Canadian conditions.

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